

**BEAMBEPREP**

PAKISTAN ENTRANCE EXAMINATION ENGINE

**SCAN TO SOLVE LIVE**Timer, instant scoring, and
percentile ranks on
beambeprep.com

DUHS KARACHI

DUHS Karachi MDCAT 2021 Official Paper

Official Annual Full-Length Practice Examination (FLP) · Complete Solved Paper

🛡️ Official Admitting Board: Dow University of Health Sciences Karachi 📁 Archive Code: BEAMBE-FLP-DUHS-2021

🕒 Duration: 150 Minutes (2h 30m)

92

TOTAL QUESTIONS

150m

OFFICIAL DURATION

+1 / 0.00

ZERO NEGATIVE MARKING

92

MAXIMUM MARKS

📄 EXAMINATION BLUEPRINT & SUBJECT WEIGHTAGE

Biology**36 MCQs**

39.1% weight

Chemistry**24 MCQs**

26.1% weight

Physics**20 MCQs**

21.7% weight

English**12 MCQs**

13.0% weight

BIO SECTION: BIOLOGY

Questions 1 to 36 (36 MCQs)

Q1. BIO

If fertilization occurs, the young embryo is implanted into the:

- (A) Epimetrium
- (B) Myometrium
- (C) Perimetrium
- (D) Endometrium

Q2. BIO

Hormones called gonadotropins are released by which gland?

- (A) Ovaries
- (B) Hypothalamus
- (C) Pituitary gland
- (D) Testes

Q3. BIO

Which of the following is found at the ends of long bones, in the nose, larynx, and trachea?

- (A) Elastic cartilage
- (B) Fibrous cartilage
- (C) Perichondrium
- (D) Hyaline cartilage

Q4. BIO

A muscle with characteristics like spontaneous contraction, one nucleus per cell, and no control over contraction is most likely:

- (A) Smooth muscle
- (B) Cardiac muscle
- (C) Skeletal muscle
- (D) Visceral muscle

Q5. BIO

A ball and socket joint is present at the:

- (A) Shoulder
- (B) Wrist
- (C) Elbow
- (D) Knee

Q6. BIO

At a temperature higher than optimum, enzymatic activity decreases because of:

- (A) Saturation
- (B) Inhibition
- (C) Denaturation
- (D) Composition

Q7. BIO

The smaller subunit (40S) of a ribosome combines with the larger subunit (60S) in the presence of Mg^{2+} ions to form an active particle of:

- (A) 100S
- (B) 208S
- (C) 80S
- (D) 70S

Q8. BIO

The natural bacterial flora is beneficial to humans because it:

- (A) Interferes with pathogenic colonization
- (B) Develops resistance against antigens
- (C) Develops resistance against physical agents
- (D) Produces antibiotics against pathogens

Q9. BIO

In bacteria, resistance against heat is provided by:

- (A) Granules
- (B) Cysts
- (C) Spores
- (D) Plasmids

Q10. BIO

These hormones perform antagonistic functions EXCEPT:

- (A) Growth hormone and somatostatin
- (B) Calcitonin and parathormone
- (C) Adrenaline and noradrenaline
- (D) Insulin and glucagon

Q11. BIO

Which organelle contains hydrolytic enzymes?

- (A) Endoplasmic reticulum
- (B) Ribosomes
- (C) Lysosomes
- (D) Cell wall

Q12. BIO

The number and sequence of amino acids in a polypeptide chain is determined by the:

- (A) Primary structure
- (B) Secondary structure
- (C) Tertiary structure
- (D) Quaternary structure

Q13. BIO

Carbohydrates are organic compounds containing:

- (A) Carbon, nitrogen, and potassium
- (B) Carbon, hydrogen, and chlorine
- (C) Carbon, nitrogen, and oxygen
- (D) Carbon, hydrogen, and oxygen

Q14. BIO

Most of the RNA in a cell is present in the:

- (A) Cell membrane
- (B) Cytoplasm
- (C) Nucleolus
- (D) Lysosomes

Q15. BIO

Turgidity in plant cells is primarily maintained by the:

- (A) Cell wall pressure
- (B) Internal pressure
- (C) Vacuole
- (D) Osmotic pressure

Q16. BIO

Chlorophyll pigments are present in which plastid?

- (A) Chloroplast
- (B) Chromoplast
- (C) Elaioplast
- (D) Amyloplast

Q17. BIO

Xanthophylls are pigments that appear:

- (A) Yellow
- (B) Red
- (C) Orange
- (D) Green

Q18. BIO

Which of the following organelles possesses its own circular DNA?

- (A) Endoplasmic reticulum
- (B) Lysosomes
- (C) Mitochondria
- (D) Ribosomes

Q19. BIO

Which organelle plays a direct role in plant cell wall formation?

- (A) Ribosomes
- (B) Cell membrane
- (C) Plasmids
- (D) Golgi apparatus

Q20. BIO

Steroid hormone synthesis occurs predominantly in the:

- (A) Rough endoplasmic reticulum
- (B) Smooth endoplasmic reticulum
- (C) Golgi apparatus
- (D) Ribosomes

Q21. BIO

The master gland of the human endocrine system is the:

- (A) Pituitary gland
- (B) Thyroid gland
- (C) Parathyroid gland
- (D) Mammary gland

Q22. BIO

The primary chemical end products of the light-dependent reactions of photosynthesis are:

- (A) ADP and NADPH
- (B) ATP and NADPH
- (C) CO₂ and H₂O
- (D) NADPH and AMP

Q23. BIO

Hydrolysis is defined as the:

- (A) Combining of molecules due to reaction with hydrogen
- (B) Combining of molecules due to reaction with water
- (C) Breaking of chemical bonds in molecules by the addition of water
- (D) Breaking of chemical bonds in molecules by the addition of hydrogen

Q24. BIO

Which of the following is a structural protein?

- (A) Pepsinogen
- (B) Casein
- (C) Enzyme
- (D) Collagen

Q25. BIO

Transmission of impulses is associated with which of the following organelles?

- (A) Smooth endoplasmic reticulum
- (B) Rough endoplasmic reticulum
- (C) Golgi apparatus
- (D) Ribosomes

Q26. BIO

The normal pH of human blood is maintained between:

- (A) 7.45 to 7.55
- (B) 7.35 to 7.45
- (C) 7.15 to 7.25
- (D) 7.25 to 7.35

Q27. BIO

In an X-linked recessive disease, an affected woman married to a normal man will have what percentage of affected daughters?

- (A) 0
- (B) 0.25
- (C) 0.5
- (D) 1

Q28. BIO

The number of ATP used to produce one glucose molecule in the Calvin cycle is:

- (A) 18
- (B) 27
- (C) 9
- (D) 36

Q29. BIO

Which hexose is most important from a biological point of view?

- (A) Mannose
- (B) Fructose
- (C) Glucose
- (D) Lactose

Q30. BIO

Chromosomes that are the same in males and females are called:

- (A) X chromosomes
- (B) Y chromosomes
- (C) Sex chromosomes
- (D) Autosomes

Q31. BIO

In the light reaction, water is used in:

- (A) Reduction
- (B) Oxidation
- (C) Photolysis
- (D) Oxygenation

Q32. BIO

Light reaction takes place in which part of the chloroplast?

- (A) Thylakoid
- (B) Stroma
- (C) Lamella
- (D) Membrane

Q33. BIO

The outermost living boundary of the cell is:

- (A) Cell wall
- (B) Cell membrane
- (C) Cytoplasm
- (D) Nuclear membrane

Q34. BIO

The sensation of pain is produced by:

- (A) Thermoreceptor
- (B) Photoreceptor
- (C) Chemoreceptor
- (D) Nociceptors

Q35. BIO

The resting membrane potential is:

- (A) -60 mV
- (B) -70 mV
- (C) -50 mV
- (D) -40 mV

Q36. BIO

Which neurotransmitter is present in the peripheral nervous system?

- (A) Epinephrine
- (B) Acetylcholine
- (C) Dopamine
- (D) Serotonin

CHEM SECTION: CHEMISTRY

Questions 37 to 60 (24 MCQs)

Q37. CHEM

Two ice blocks stick together due to:

- (A) London dispersion forces
- (B) Dipole-dipole forces
- (C) Hydrogen bonding
- (D) All of the above options are correct

Q38. CHEM

The unit of rate constant is the same as for:

- (A) First order reaction
- (B) Second order reaction
- (C) Third order reaction
- (D) Zero order reaction

Q39. CHEM

Reduction occurs at:

- (A) Anode
- (B) Cathode
- (C) Salt bridge
- (D) None of these options are correct

Q40. CHEM

Electron affinity decreases down the group due to:

- (A) Increase in atomic radius
- (B) Decrease in atomic radius
- (C) Increase in electronegativity
- (D) All of the above options are correct

Q41. CHEM

Which one is least ionic?

- (A) NaCl
- (B) AlCl₃
- (C) MgCl₂
- (D) KCl

Q42. CHEM

Diamond is:

- (A) Covalent solid
- (B) Molecular solid
- (C) Metallic solid
- (D) Ionic solid

Q43. CHEM

What is the most common gas in the environment?

- (A) Oxygen
- (B) Nitrogen
- (C) Carbon dioxide
- (D) Helium

Q44. CHEM

Which one of the following has greater bond energy?

- (A) HF
- (B) HCl
- (C) HBr
- (D) HI

Q45. CHEM

The oxidation number of an element in free state is:

- (A) 1
- (B) 2
- (C) 0
- (D) -1

Q46. CHEM

Homocyclic hydrocarbons are further divided into:

- (A) Alicyclic and aromatic
- (B) Carbocyclic and heterocyclic
- (C) Acyclic and heterocyclic
- (D) Heterocyclic and aromatic

Q47. CHEMWhich contains sp^2 hybridization?

- (A) Methane
- (B) Ethane
- (C) Alkyne
- (D) None of these options are correct

Q48. CHEM

Geometric isomerism is shown by:

- (A) Alkanes
- (B) Alkenes
- (C) Alkynes
- (D) All of the above options are correct

Q49. CHEM $C_nH_{2n}O_2$ is the general molecular formula of:

- (A) Alcohols
- (B) Ketones
- (C) Carboxylic acids
- (D) Ethers

Q50. CHEM

Concentrated 50% NaOH is used in:

- (A) Aldol condensation reaction
- (B) Cannizzaro reaction
- (C) Clemmensen reduction reaction
- (D) Wolff-Kishner reduction reaction

Q51. CHEM

Carboxylic acids are soluble in water due to:

- (A) Dipole-dipole forces
- (B) London dispersion forces
- (C) Hydrogen bonding
- (D) Covalent bonding

Q52. CHEM

Esterification occurs in the presence of:

- (A) Aldehydes and ketones
- (B) Alcohols and ketones
- (C) Carboxylic acids and alcohols
- (D) Carboxylic acids and aldehydes

Q53. CHEM

Benzene can be prepared from sodium benzoate by reaction with:

- (A) AlCl_3
- (B) NaOH
- (C) Chlorobenzene
- (D) Cumene

Q54. CHEM

Empirical formula is related to molecular formula by:

- (A) Molecular formula = $\frac{\text{Empirical formula}}{n}$
- (B) Molecular formula = $n \times (\text{Empirical formula})$
- (C) Molecular formula = $2n \times (\text{Empirical formula})$
- (D) Molecular formula = $n + (\text{Molecular formula})$

Q55. CHEM

Which one is more reactive among halogens?

- (A) F_2
- (B) Cl_2
- (C) Br_2
- (D) I_2

Q56. CHEM

One calorie is equal to:

- (A) 4.18 kJ
- (B) 4.18 J
- (C) 18 J
- (D) 18 kJ

Q57. CHEM

The net enthalpy change in a chemical reaction is the same whether it is brought about in two or more different ways in one or several steps. This is known as:

- (A) Joule's law
- (B) Law of conservation of energy
- (C) Hess's law
- (D) Henry's law

Q58. CHEM

Which is not true about the rate of reaction?

- (A) It is independent of the concentration of reactants.
- (B) It depends upon the temperature.
- (C) It does not depend upon the order of reaction.
- (D) All of the above options are correct.

Q59. CHEM

Which one is an s-block element?

- (A) B
- (B) K
- (C) Ca
- (D) Cumene

Q60. CHEM

Bond angle is 120° in:

- (A) Ethane
- (B) Ethyne
- (C) Ethene
- (D) Cyclopropane

PHY SECTION: PHYSICS

Questions 61 to 80 (20 MCQs)

Q61. PHY

In a perfectly elastic collision:

- (A) Only momentum is conserved
- (B) Only total energy is conserved
- (C) Only kinetic energy is conserved
- (D) Momentum, kinetic energy, and total energy are conserved

Q62. PHY

The slope of a displacement–time graph is:

- (A) Velocity
- (B) Displacement
- (C) Acceleration
- (D) Distance

Q63. PHY

An object moving along a circular path of radius 1 m covers a distance of 2 m along the circumference. What will be the angular displacement covered by it?

- (A) $\frac{1}{2}$ radian
- (B) 2 radians
- (C) 3 radians
- (D) $\frac{2}{3}$ radian

Q64. PHY

Speed of sound is 332 m/s at 0°C. What will be its value at 10°C?

- (A) 332 m/s
- (B) 338.1 m/s
- (C) 332.61 m/s
- (D) 334.1 m/s

Q65. PHYIn molar specific heat, the equation $C_p - C_v = R$ shows that:

- (A) $C_p < C_v$
- (B) $C_p = C_v$
- (C) $C_p > C_v$
- (D) $C_p = \text{Constant}$

Q66. PHY

The thermodynamic process during which volume of the system remains constant is:

- (A) Isothermal
- (B) Isobaric
- (C) Isochoric
- (D) Adiabatic

Q67. PHYIf two capacitors of capacitance $2\ \mu\text{F}$ and $6\ \mu\text{F}$ are connected in parallel, the equivalent capacitance of the combination will be:

- (A) $8\ \mu\text{F}$
- (B) $\frac{3}{2}\ \mu\text{F}$
- (C) $4\ \mu\text{F}$
- (D) $12\ \mu\text{F}$

Q68. PHY

Power transfer will be maximum when:

- (A) $R > r$
- (B) $R < r$
- (C) $R = r$
- (D) $R = \frac{1}{r}$

Q69. PHY

A wire is stretched so that its radius of cross-section becomes half. Then resistance of the wire will be:

- (A) $4R$
- (B) $\frac{R}{4}$
- (C) $8R$
- (D) $16R$

Q70. PHY

When a charged particle enters a magnetic field parallel to the field lines, it:

- (A) Deflects towards North
- (B) Deflects towards South
- (C) Moves straight
- (D) Moves in a circular path

Q71. PHY

Magnetic flux is maximum when the angle between the magnetic field and the vector area is:

- (A) 0°
- (B) 45°
- (C) 90°
- (D) 180°

Q72. PHY

The domestic electricity supply in Pakistan has a frequency of:

- (A) 70 Hz
- (B) 50 Hz
- (C) 100 Hz
- (D) 30 Hz

Q73. PHY

The device that increases or decreases the electromotive force (emf) is called a:

- (A) AC generator
- (B) Motor
- (C) Transformer
- (D) DC generator

Q74. PHY

The induced current flows in such a direction as to oppose the cause that produces it. This statement is:

- (A) Ampere's Law
- (B) Faraday's Law
- (C) Lenz's Law
- (D) Joule's Law

Q75. PHY

The device used for conversion of AC into DC is a:

- (A) Diode
- (B) Amplifier
- (C) Rectifier
- (D) Transistor

Q76. PHY

The process of conversion of AC into DC is called:

- (A) Rectification
- (B) Amplification
- (C) Rectifier
- (D) Conversion

Q77. PHY

A 32 g phosphorus sample decays and 2 g remains undecayed after 60 days. The half-life of phosphorus is:

- (A) 5 days
- (B) 6 days
- (C) 10 days
- (D) 15 days

Q78. PHY

The SI unit of gravitational potential is:

- (A) J/kg
- (B) J/(m · kg)
- (C) J/(m · s)
- (D) J/s

Q79. PHY

In nuclear radiography for medical diagnosis, which rays are used?

- (A) Alpha particles
- (B) UV rays
- (C) Gamma rays
- (D) X-rays

Q80. PHY

The SI unit of linear momentum is:

- (A) N · m
- (B) N/s
- (C) N · s
- (D) N · s²

ENG SECTION: ENGLISH

Questions 81 to 92 (12 MCQs)

Q81. ENG

Fill in the blanks with the most appropriate option:

When we went to cinema, the film _____.

- (A) Already started
- (B) Had already started
- (C) Would already start
- (D) Started already

Q82. ENG

The soup _____ good.

- (A) Taste
- (B) Tastes
- (C) Is tasting
- (D) Will tasting

Q83. ENG

She _____ unconscious since 4 o'clock.

- (A) Is
- (B) Was
- (C) Has been
- (D) Would

Q84. ENG

We will stay here _____ Monday.

- (A) Until
- (B) Till
- (C) Still
- (D) Since

Q85. ENG

The word curiosity means:

- (A) Cruel
- (B) Keen
- (C) Angry
- (D) Killing

Q86. ENG

DRAWBACK, this word is a combination of:

- (A) Verb + Adjective
- (B) Noun + Adjective
- (C) Verb + Noun
- (D) Verb + Adverb

Q87. ENG

I wish I _____ the answer.

- (A) Will know
- (B) Knew
- (C) Have known
- (D) Know

Q88. ENG

What does the word "Analogue" mean?

- (A) Opposite
- (B) Comparable
- (C) Behind
- (D) Clock

Q89. ENG

What does the word "Pulsating" mean?

- (A) Throbbing
- (B) Pressure
- (C) Fluid
- (D) Heart beat

Q90. ENG

The person in charge of a school is called:

- (A) Principal
- (B) Principle
- (C) Head
- (D) Staff

Q91. ENG

Break a leg is commonly used to:

- (A) Curse someone
- (B) Physically harm someone
- (C) Wish good luck to someone
- (D) Teach someone a lesson

Q92. ENG

Bite the bullet is commonly used to:

- (A) Accept defeat
- (B) Accept consequences
- (C) Accept death
- (D) Accept bad faith

OFFICIAL VERIFIED ANSWER KEY

DUHS Karachi MDCAT 2021 Official Paper • Rapid Self-Grading Grid

[Online Portal >](#)

Q#	KEY	SUB	Q#	KEY	SUB	Q#	KEY	SUB	Q#	KEY	SUB	Q#	KEY	SUB
1	D	BIO	20	B	BIO	39	B	CHEM	58	A	CHEM	77	D	PHY
2	C	BIO	21	A	BIO	40	A	CHEM	59	B	CHEM	78	A	PHY
3	D	BIO	22	B	BIO	41	B	CHEM	60	C	CHEM	79	C	PHY
4	A	BIO	23	C	BIO	42	A	CHEM	61	D	PHY	80	C	PHY
5	A	BIO	24	D	BIO	43	B	CHEM	62	A	PHY	81	B	ENG
6	C	BIO	25	A	BIO	44	A	CHEM	63	B	PHY	82	B	ENG
7	C	BIO	26	B	BIO	45	C	CHEM	64	B	PHY	83	C	ENG
8	A	BIO	27	A	BIO	46	A	CHEM	65	C	PHY	84	B	ENG
9	C	BIO	28	A	BIO	47	D	CHEM	66	C	PHY	85	B	ENG
10	C	BIO	29	C	BIO	48	B	CHEM	67	A	PHY	86	D	ENG
11	C	BIO	30	D	BIO	49	C	CHEM	68	C	PHY	87	B	ENG
12	A	BIO	31	C	BIO	50	B	CHEM	69	D	PHY	88	B	ENG
13	D	BIO	32	A	BIO	51	C	CHEM	70	C	PHY	89	A	ENG
14	B	BIO	33	B	BIO	52	C	CHEM	71	A	PHY	90	A	ENG
15	C	BIO	34	D	BIO	53	B	CHEM	72	B	PHY	91	C	ENG
16	A	BIO	35	B	BIO	54	B	CHEM	73	C	PHY	92	B	ENG
17	A	BIO	36	B	BIO	55	A	CHEM	74	C	PHY			
18	C	BIO	37	C	CHEM	56	B	CHEM	75	C	PHY			
19	D	BIO	38	D	CHEM	57	C	CHEM	76	A	PHY			

SUBJECT-WISE PERFORMANCE BREAKDOWN

SUBJECT	MAX	YOUR SCORE	ACCURACY
Biology	36	_____	_____ %
Chemistry	24	_____	_____ %
Physics	20	_____	_____ %
English	12	_____	_____ %
TOTAL	92	_____	_____ %

PMDC PROVINCIAL MERIT FORMULA

Official Weightage Law:

- MDCAT Component (50%): (Your Score / 92) × 50
- FSc / HSSC Component (40%): (FSc Marks / 1100) × 40
- Matric / SSC Component (10%): (Matric Marks / 1100) × 10

Estimated Provincial Merit Aggregate: _____ %

PROPOLIS COGNITIVE ERROR AUTOPSIES

Step-by-step conceptual derivations, formula working, and distractor autopsies for every question.

Question #1 Key: (D)

BIOLOGY
14. Reproduction

If fertilization occurs, the young embryo is implanted into the:

CORE CONCEPT & DERIVATION

The endometrium is the inner glandular mucosal layer of the uterine wall that undergoes cyclical preparation for blastocyst implantation.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Following fertilization in the fallopian tube, the cleaving blastocyst enters the uterine cavity.
- Implantation proceeds as the trophoblast penetrates and embeds into the vascularized, receptive endometrial stroma.

Why other options are incorrect:

- **Option A:** Epimetrium is an obsolete anatomical term occasionally used synonymously with perimetrium; it is not an implantation surface.
- **Option B:** Myometrium is the intermediate muscular tunic composed of smooth muscle bundles responsible for expulsive uterine contractions during parturition.
- **Option C:** Perimetrium is the outer serosal coat derived from the peritoneum covering the external uterine surface.

Question #2 Key: (C)

BIOLOGY
13. Chemical Coordination

Hormones called gonadotropins are released by which gland?

CORE CONCEPT & DERIVATION

Gonadotropins are glycoprotein hormones secreted by the anterior pituitary gland that regulate gonadal endocrine function and gametogenesis.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Gonadotroph cells in the anterior pituitary gland synthesize and secrete follicle-stimulating hormone (FSH) and luteinizing hormone (LH).
- Because FSH and LH directly stimulate target tissues within the gonads, they are classified as gonadotropins.

Why other options are incorrect:

- **Option A:** Ovaries are target organs that produce steroid sex hormones (estrogen and progesterone), not gonadotropins.
- **Option B:** The hypothalamus secretes gonadotropin-releasing hormone (GnRH), a peptide neurohormone that acts as a releasing factor rather than a gonadotropin.
- **Option D:** Testes are male target gonads that synthesize androgens (principally testosterone) under gonadotropic regulation.

Question #3 Key: (D)BIOLOGY
11. Support & Movement

Which of the following is found at the ends of long bones, in the nose, larynx, and trachea?

CORE CONCEPT & DERIVATION

Hyaline cartilage is the most widespread cartilage type, characterized by fine type II collagen fibrils embedded in an amorphous, hydrated glycosaminoglycan matrix.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Hyaline cartilage provides frictionless articulating surfaces as articular cartilage over the epiphyseal ends of long bones.
- It also forms the cartilaginous skeleton of the external nose, laryngeal thyroid and cricoid plates, and C-shaped rings of the trachea.

Why other options are incorrect:

- **Option A:** Elastic cartilage contains dense networks of elastin fibers and is restricted to the auricle (pinna), external acoustic meatus, and epiglottis.
- **Option B:** Fibrous cartilage possesses dense parallel bundles of coarse type I collagen fibers, occurring in intervertebral discs and the pubic symphysis.
- **Option C:** Perichondrium is the outer fibrous sheath of vascularized dense connective tissue that invests non-articular cartilage, not a cartilage tissue itself.

Question #4 Key: (A)BIOLOGY
11. Support & Movement

A muscle with characteristics like spontaneous contraction, one nucleus per cell, and no contro...

CORE CONCEPT & DERIVATION

Smooth muscle cells are spindle-shaped, non-striated, uninucleated myocytes under involuntary autonomic regulation capable of sustained myogenic contractions.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Smooth muscle cells possess a single, centrally placed nucleus per cell and lack transverse striations.
- Single-unit smooth muscle displays intrinsic myogenic rhythmicity (spontaneous depolarization) and operates beyond conscious voluntary control.
- Although visceral muscle is a contextual synonym, smooth muscle is the canonical histological classification keyed by the examining board.

Why other options are incorrect:

- **Option B:** Cardiac muscle fibers are striated, branched, interconnected by intercalated discs, and restricted exclusively to the myocardium.
- **Option C:** Skeletal muscle fibers are cylindrical, multi-nucleated, transversely striated, and subject to voluntary somatic motor control.
- **Option D:** Visceral muscle is a gross macroscopic anatomical designation rather than the primary histological category.

Question #5 Key: (A)BIOLOGY
11. Support & Movement

A ball and socket joint is present at the:

CORE CONCEPT & DERIVATION

A ball and socket joint (spheroidal joint) is a multiaxial synovial joint where a spherical bone head articulates within a cup-shaped cavity to allow movement in all cardinal planes.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The glenohumeral (shoulder) joint is formed by the head of the humerus articulating with the glenoid cavity of the scapula.
- This morphology permits multiaxial movements: flexion, extension, abduction, adduction, medial rotation, lateral rotation, and circumduction.

Why other options are incorrect:

- **Option B:** The radiocarpal (wrist) joint is a biaxial condyloid (ellipsoid) joint permitting motion in two axes without axial rotation.
- **Option C:** The humeroulnar (elbow) joint is a uniaxial hinge joint limited to flexion and extension.
- **Option D:** The tibiofemoral (knee) joint is a modified bicondylar hinge joint primarily limited to motion in the sagittal plane.

Question #6 Key: (C)BIOLOGY
03. Enzymes

At a temperature higher than optimum, enzymatic activity decreases because of:

CORE CONCEPT & DERIVATION

Excessive thermal energy disrupts non-covalent intramolecular bonds stabilizing the tertiary structure of proteins, causing denaturation of the catalytic active site.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Enzymatic active sites rely on precise three-dimensional conformations stabilized by hydrogen bonds, ionic interactions, and hydrophobic associations.
- Thermal agitation above the optimum temperature breaks these weak stabilizing interactions, causing irreversible unfolding (denaturation) and loss of substrate binding.

Why other options are incorrect:

- **Option A:** Saturation occurs when substrate concentrations are sufficiently elevated such that all catalytic sites are continuously occupied.
- **Option B:** Inhibition involves chemical modifiers or ligand analogs that reversibly or irreversibly impair enzyme turnover, not non-specific thermal disruption.
- **Option D:** Composition refers to the static covalent primary sequence of amino acids, which remains intact during thermal unfolding.

Question #7 Key: (C)BIOLOGY
01. Cell

The smaller subunit ([Formula]) of a ribosome combines with the larger subunit ([Formula])...

CORE CONCEPT & DERIVATION

Eukaryotic ribosomes sediment at 80S, assembled through the non-additive association of a 40S small subunit and a 60S large subunit stabilized by divalent cations.

Formula / Rule / Reaction:**Solution:**

- Svedberg units (S) quantify sedimentation velocity in an ultracentrifuge, which is a function of both mass and hydrodynamic surface area.
- Because sedimentation rates are non-additive, the assembly of the eukaryotic 40S and 60S subunits in the presence of physiological Mg^{2+} produces an 80S monosome.

Why other options are incorrect:

- **Option A:** 100S corresponds to a dimerized form of bacterial 70S ribosomes observed under specific stress or high divalent ion concentrations.
- **Option B:** 208S is an arbitrary numerical distractor with no physiological or biophysical basis in ribosomology.
- **Option D:** 70S is the sedimentation coefficient of prokaryotic, mitochondrial, and plastid ribosomes assembled from 30S and 50S subunits.

Question #8 Key: (A)BIOLOGY
08. Immunity

The natural bacterial flora is beneficial to humans because it:

CORE CONCEPT & DERIVATION

Commensal indigenous microflora protects host epithelia through colonization resistance, preventing the adherence, establishment, and proliferation of exogenous pathogens.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Normal microbiota occupies host epithelial surface receptors, outcompeting potential pathogens for cellular binding sites.
- Commensals also consume accessible luminal nutrients and secrete metabolic byproducts (such as short-chain fatty acids) that lower microenvironmental pH, suppressing pathogenic invasion.

Why other options are incorrect:

- **Option B:** Antigens stimulate adaptive host immune defenses; bacteria do not confer physiological resistance against antigenic molecules.
- **Option C:** Commensal bacteria provide no protective barrier or resistance mechanisms against physical insults such as mechanical trauma or thermal injury.
- **Option D:** Although select species synthesize localized bacteriocins, indigenous microflora does not produce systemic clinical antibiotics.

Question #9 Key: (C)BIOLOGY
17. Biotechnology*In bacteria, resistance against heat is provided by:***CORE CONCEPT & DERIVATION**

Bacterial endospores are cryptobiotic, highly dehydrated dormant structures reinforced with calcium dipicolinate and keratin-like protein coats to withstand extreme thermal stress.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Under nutrient starvation, specific genera such as *Bacillus* and *Clostridium* initiate sporulation to generate endospores.
- The endospore core contains high concentrations of dipicolinic acid complexed with calcium ions (calcium dipicolinate) alongside small acid-soluble proteins (SASPs) that protect DNA from heat-induced denaturation.

Why other options are incorrect:

- **Option A:** Granules are non-membranous cytoplasmic inclusions used exclusively to store glycogen, polyphosphate, or sulfur.
- **Option B:** Bacterial cysts (e.g., in *Azotobacter*) are dormant cells with thickened coats that resist desiccation, but they remain sensitive to moist heat.
- **Option D:** Plasmids are autonomous circular extrachromosomal DNA elements that mediate genetic transfer and antibiotic resistance, not physical heat tolerance.

Question #10 Key: (C)BIOLOGY
13. Chemical Coordination*These hormones perform antagonistic functions EXCEPT:***CORE CONCEPT & DERIVATION**

Antagonistic hormone pairs exert diametrically opposite physiological effects on homeostatic parameters; adrenaline and noradrenaline act cooperatively in sympathetic signaling.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Adrenaline (epinephrine) and noradrenaline (norepinephrine) are catecholamines secreted by the adrenal medulla that act synergistically to execute the acute fight-or-flight response.
- Because they reinforce rather than counterbalance each other during sympathetic stimulation, they are not antagonistic.

Why other options are incorrect:

- **Option A:** Growth hormone promotes somatic development, whereas somatostatin acts as growth hormone-inhibiting hormone (GHIH) to block its release.
- **Option B:** Calcitonin lowers circulating blood calcium by stimulating bone deposition, whereas parathormone (PTH) elevates blood calcium via osteolysis.
- **Option D:** Insulin decreases blood glucose by stimulating cellular uptake and glycogenesis, whereas glucagon elevates blood glucose through glycogenolysis.

Question #11 Key: (C)BIOLOGY
01. Cell*Which organelle contains hydrolytic enzymes?***CORE CONCEPT & DERIVATION**

Lysosomes are single-membrane eukaryotic organelles packed with acidic hydrolases responsible for intracellular degradation and autophagy.

Formula / Rule / Reaction:**Solution:**

- Lysosomes maintain an acidic internal luminal pH (approximately 4.5 to 5.0) via vacuolar H^+ -ATPase proton pumps.
- This internal compartment segregates more than forty distinct hydrolytic enzymes (including proteases, nucleases, lipases, and glycosidases) to safely degrade endocytosed material and cellular debris.

Why other options are incorrect:

- **Option A:** The endoplasmic reticulum coordinates protein translation, folding, lipid assembly, and calcium storage, but does not sequester broad acid hydrolases.
- **Option B:** Ribosomes are non-membranous ribonucleoprotein complexes that catalyze peptide bond formation during translation.
- **Option D:** The cell wall is a non-living extracellular exoskeleton of structural polysaccharides outside the plasma membrane.

Question #12 Key: (A)BIOLOGY
02. Biomolecules*The number and sequence of amino acids in a polypeptide chain is determined by the:***CORE CONCEPT & DERIVATION**

The primary structure of a protein is the specific linear sequence and total count of amino acids linked together by covalent peptide bonds.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- The linear sequence of amino acids in a polypeptide is genetically dictated by the triplet codon sequence of mRNA transcribed from DNA.
- This defined sequence constitutes the primary structure, which encodes all thermodynamic information necessary for downstream spatial folding.

Why other options are incorrect:

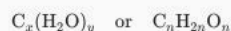
- **Option B:** Secondary structure refers to localized repeating configurations stabilized by peptide backbone hydrogen bonding, such as alpha-helices and beta-pleated sheets.
- **Option C:** Tertiary structure denotes the overall three-dimensional folding of a single polypeptide stabilized by side-chain hydrophobic interactions, hydrogen bonds, salt bridges, and disulfide links.
- **Option D:** Quaternary structure describes the multimeric assembly and spatial arrangement of multiple distinct polypeptide subunits.

Question #13 Key: (D)BIOLOGY
02. Biomolecules

Carbohydrates are organic compounds containing:

CORE CONCEPT & DERIVATION

Carbohydrates are polyhydroxy aldehydes or polyhydroxy ketones composed solely of carbon, hydrogen, and oxygen, generally following the stoichiometric ratio of water.

Formula / Rule / Reaction:**Solution:**

- Carbohydrates literally designate "hydrates of carbon" because their empirical composition comprises carbon together with hydrogen and oxygen in a 2:1 atomic ratio.
- Fundamental monosaccharides (such as glucose, $C_6H_{12}O_6$) and polysaccharides (such as starch and cellulose) consist strictly of carbon, hydrogen, and oxygen atoms.

Why other options are incorrect:

- Option A:** Nitrogen and potassium are not native constituents of basic carbohydrates; potassium functions as an inorganic electrolyte.
- Option B:** Chlorine is a halogen found as an extracellular anion (chloride), not within carbohydrate structures.
- Option C:** Nitrogen is an elemental hallmark of proteins, amino acids, and nucleic acids, but is absent in standard carbohydrates.

Question #14 Key: (B)BIOLOGY
01. Cell

Most of the RNA in a cell is present in the:

CORE CONCEPT & DERIVATION

The vast majority of cellular RNA resides within the cytoplasm, primarily distributed as ribosomal RNA (rRNA) in assembled ribosomes and transfer RNA (tRNA).

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Ribosomal RNA accounts for roughly 80% of total cellular RNA, while transfer RNA represents another 10% to 15%.
- Because functional ribosomes and aminoacyl-tRNAs are localized in the cytosol for translation, up to 90% of a cell's steady-state RNA pool is situated in the cytoplasm.
- Note on board errata:* Past paper answer keys occasionally miskey the nucleolus because it exhibits the highest localized rate of transcription per unit volume; however, standard textbooks confirm that steady-state cellular abundance resides overwhelmingly in the cytoplasm.

Why other options are incorrect:

- Option A:** The cell membrane is a lipid-protein boundary and contains no functional pool of RNA.
- Option C:** The nucleolus is the site of rRNA gene transcription and preribosomal assembly, harboring approximately 5% to 10% of total cellular RNA at any given instant.
- Option D:** Lysosomes contain hydrolytic ribonucleases that degrade endocytosed RNA rather than storing cellular RNA.

Question #15 Key: (C)BIOLOGY
10. Homeostasis*Turgidity in plant cells is primarily maintained by the:***CORE CONCEPT & DERIVATION**

The plant central vacuole accumulates inorganic ions and metabolites via tonoplast active transport, creating a hypertonic lumen that drives osmotic water entry to generate turgor pressure.

Formula / Rule / Reaction:

$$\Psi_w = \Psi_s + \Psi_p$$

Solution:

- Transporters in the tonoplast pump mineral ions into the central vacuolar sap against concentration gradients, significantly depressing the vacuolar solute potential (Ψ_s).
- Water flows osmotically into the vacuole down the water potential gradient, expanding the vacuolar volume and driving turgor pressure against the cell wall to support soft tissues.

Why other options are incorrect:

- **Option A:** Wall pressure is the opposing mechanical counter-force exerted by the rigid cellulose wall against expanding protoplasm, not the active generating organelle.
- **Option B:** Internal pressure is an unspecific mechanical term rather than the specific subcellular organelle maintaining hydrostatic support.
- **Option D:** Osmotic pressure is a physical solution property, whereas the vacuole is the biological organelle that establishes and regulates osmotic balance.

Question #16 Key: (A)BIOLOGY
01. Cell*Chlorophyll pigments are present in which plastid?***CORE CONCEPT & DERIVATION**

Chlorophyll pigments are embedded within the thylakoid membranes of chloroplasts to absorb light energy during the photosynthetic light reactions.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Chloroplasts are double-membrane plastids containing an internal network of flattened membranous sacs called thylakoids.
- Hydrophobic phytol tails anchor chlorophyll molecules into thylakoid lipid bilayers, assembling them into antenna complexes and reaction centers.

Why other options are incorrect:

- **Option B:** Chromoplasts synthesize and accumulate non-photosynthetic carotenoids (carotenes and xanthophylls) that impart yellow, orange, and red coloration to petals and ripening fruits.
- **Option C:** Elaioplasts (sometimes spelled elipoplasts) are non-pigmented leucoplasts specialized for lipid and oil storage in seeds.
- **Option D:** Amyloplasts are non-pigmented leucoplasts that synthesize and store polymeric starch granules in roots and storage tubers.

Question #17 Key: (A)BIOLOGY
04. Bioenergetics*Xanthophylls are pigments that appear:***CORE CONCEPT & DERIVATION**

Xanthophylls are oxygenated carotenoid derivatives that absorb blue and violet wavelengths of the visible spectrum and transmit yellow light.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Carotenoids are divided into two chemical groups: pure hydrocarbon carotenes and oxygenated xanthophylls.
- Because xanthophylls (such as lutein and zeaxanthin) absorb light predominantly in the 400 to 500 nm range, they reflect and transmit light perceived as yellow.

Why other options are incorrect:

- **Option B:** Red hues in plant organs typically arise from anthocyanin flavonoids stored in vacuoles or specific linear carotenes such as lycopene.
- **Option C:** Orange pigmentation is characteristic of pure carotene hydrocarbons, notably beta-carotene.
- **Option D:** Green pigmentation is produced by chlorophyll a and chlorophyll b absorbing blue and red wavelengths.

Question #19 Key: (D)BIOLOGY
01. Cell*Which organelle plays a direct role in plant cell wall formation?***CORE CONCEPT & DERIVATION**

The Golgi apparatus synthesizes non-cellulosic wall polysaccharides and packages them into vesicles that assemble to establish the phragmoplast and cell plate during cytokinesis.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- During plant cell cytokinesis, Golgi-derived dictyosome vesicles migrate along microtubules to the division plane.
- These vesicles coalesce to construct the cell plate (middle lamella), discharging matrix components including pectins and hemicellulose via exocytosis.

Why other options are incorrect:

- **Option A:** Ribosomes synthesize polypeptides and cytosolic enzymes; they do not synthesize or traffic wall polysaccharides.
- **Option B:** While rosette cellulose synthase complexes sit in the plasma membrane, the vesicular synthesis and transport of matrix polysaccharides is directed by the Golgi apparatus.
- **Option C:** Plasmids are bacterial extrachromosomal DNA rings that play no physiological role in plant cytokinetic wall assembly.

Question #18 Key: (C)BIOLOGY
01. Cell*Which of the following organelles possesses its own circular DNA?***CORE CONCEPT & DERIVATION**

Mitochondria are semi-autonomous endosymbiotic organelles possessing closed circular double-stranded DNA (mtDNA) and independent prokaryote-like ribosomes.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Derived from an ancestral alpha-proteobacterial endosymbiont, mitochondria retain their own genetic machinery in the matrix.
- Mitochondrial DNA encodes key polypeptide subunits of the electron transport chain, as well as mitochondrial ribosomal RNAs and tRNAs.

Why other options are incorrect:

- **Option A:** The endoplasmic reticulum is a single-membrane endomembrane system lacking intrinsic nucleic acid genomes.
- **Option B:** Lysosomes are simple membrane-bound vacuoles containing hydrolytic enzymes and possess no genome.
- **Option D:** Ribosomes are non-membranous ribonucleoprotein particles made of rRNA and structural proteins; they do not contain DNA.

Question #20 **Key: (B)**BIOLOGY
01. Cell*Steroid hormone synthesis occurs predominantly in the:***CORE CONCEPT & DERIVATION**

The smooth endoplasmic reticulum houses the membrane-bound enzymes responsible for lipid metabolism, phospholipid synthesis, and steroidogenesis.

Formula / Rule / Reaction:**Solution:**

- The smooth endoplasmic reticulum (SER) is devoid of surface ribosomes and specializes in lipid and carbohydrate biochemical modifications.
- Endocrine cells of the adrenal cortex and gonads (Leydig and granulosa cells) contain extensive SER networks dedicated to the enzymatic conversion of cholesterol into steroids.

Why other options are incorrect:

- **Option A:** The rough endoplasmic reticulum is studded with ribosomes and specializes in the translation, initial core glycosylation, and sorting of secretory and transmembrane proteins.
- **Option C:** The Golgi apparatus modifies, sorts, and packages macromolecules received from the ER, but does not synthesize steroid rings.
- **Option D:** Ribosomes are exclusively dedicated to peptide bond synthesis during mRNA translation.

Question #21 **Key: (A)**BIOLOGY
13. Chemical Coordination*The master gland of the human endocrine system is the:***CORE CONCEPT & DERIVATION**

The pituitary gland (hypophysis) is referred to as the master gland because its anterior trophic hormones regulate the activity of subordinate endocrine glands throughout the body.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- The anterior pituitary gland secretes tropic hormones including TSH, ACTH, FSH, and LH under hypothalamic control.
- These hormones stimulate peripheral endocrine organs (thyroid, adrenal cortex, and gonads) to regulate metabolism, stress responses, and reproduction.

Why other options are incorrect:

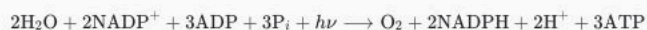
- **Option B:** The thyroid gland produces thyroid hormones (T3 and T4) and calcitonin; its synthesis is subordinated to pituitary TSH.
- **Option C:** Parathyroid glands secrete parathyroid hormone (PTH) in response to ionized calcium levels without pituitary involvement.
- **Option D:** Mammary glands are exocrine accessory reproductive structures that produce milk, not endocrine regulator glands.

Question #22 Key: (B)BIOLOGY
04. Bioenergetics

The primary chemical end products of the light-dependent reactions of photosynthesis are:

CORE CONCEPT & DERIVATION

The light reactions of photosynthesis capture solar photons within thylakoid membranes to generate chemical assimilatory power in the form of ATP and NADPH.

Formula / Rule / Reaction:**Solution:**

- Photolysis of water provides electrons to photosystems, while light-driven electron transport reduces NADP^+ to NADPH via ferredoxin-NADP⁺ reductase.
- Concurrently, chemiosmotic proton translocation across the thylakoid membrane drives ATP synthase to photophosphorylate ADP into ATP. Both products feed into the light-independent Calvin cycle.

Why other options are incorrect:

- **Option A:** ADP is a low-energy substrate consumed during photophosphorylation rather than a final energy-storing product.
- **Option C:** CO_2 is the inorganic carbon substrate reduced during the Calvin cycle, and H_2O is consumed during photolysis.
- **Option D:** AMP is not generated by the light-dependent photophosphorylation cascade; the nucleotide produced is ATP.

Question #23 Key: (C)BIOLOGY
02. Biomolecules

Hydrolysis is defined as the:

CORE CONCEPT & DERIVATION

Hydrolysis is a chemical cleavage reaction in which a covalent bond is split through the addition of a water molecule, contributing a proton to one fragment and a hydroxyl group to the other.

Formula / Rule / Reaction:**Solution:**

- The term derives from Greek *hydro* (water) and *lysis* (loosening or breaking).
- During cellular catabolism, hydrolytic enzymes use water molecules to cleave ester, peptide, and glycosidic bonds, breaking biopolymers down into their constituent monomers.

Why other options are incorrect:

- **Option A:** Combining molecules with hydrogen represents a catalytic hydrogenation or reduction reaction, not hydrolysis.
- **Option B:** Combining monomeric molecules with the concurrent elimination of water is known as condensation or dehydration synthesis.
- **Option D:** Cleaving covalent chemical bonds via molecular hydrogen is termed hydrogenolysis, not hydrolysis.

Question #24 Key: (D)BIOLOGY
02. Biomolecules*Which of the following is a structural protein?***CORE CONCEPT & DERIVATION**

Structural proteins provide mechanical support, physical framework, and tensile strength to biological tissues and cellular structures.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Collagen is an insoluble fibrous protein organized into a triple-helix quaternary conformation.
- It serves as the principal structural component of extracellular matrices, connective tissues, tendons, ligaments, cartilage, and bone matrix.

Why other options are incorrect:

- **Option A:** Pepsinogen is an inactive zymogen precursor of the digestive enzyme pepsin, functioning catalytically rather than structurally.
- **Option B:** Casein is a storage phosphoprotein present in mammalian milk that functions as a nutrient source of amino acids and minerals.
- **Option C:** Enzyme is a broad functional classification for biological catalysts that accelerate metabolic biochemical reactions.

Question #25 Key: (A)BIOLOGY
01. Cell*Transmission of impulses is associated with which of the following organelles?***CORE CONCEPT & DERIVATION**

In excitable muscle cells, the specialized smooth endoplasmic reticulum (sarcoplasmic reticulum) stores, releases, and re-sequesters calcium ions to conduct excitation-contraction impulses.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Standard provincial textbook curricula highlight transmission of impulses among the core functions of the smooth endoplasmic reticulum (SER).
- In myocytes, the sarcoplasmic reticulum conducts membrane action potentials deep into fibers via terminal cisternae, releasing Ca^{2+} to activate troponin and cross-bridge cycling.

Why other options are incorrect:

- **Option B:** Rough endoplasmic reticulum is studded with ribosomes and specializes in secretory protein synthesis, folding, and post-translational modification.
- **Option C:** The Golgi apparatus functions in glycosylation, sorting, and packaging of macromolecules into secretory vesicles.
- **Option D:** Ribosomes are non-membranous ribonucleoprotein complexes responsible for peptide bond formation during translation.

Question #26 Key: (B)BIOLOGY
10. Homeostasis

The normal pH of human blood is maintained between:

CORE CONCEPT & DERIVATION

Human systemic arterial blood pH is tightly buffered by homeostatic mechanisms within a narrow physiological range of 7.35 to 7.45.

Formula / Rule / Reaction:

$$\text{pH} = \text{p}K_a + \log\left(\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}\right)$$

Solution:

- The carbonic acid-bicarbonate buffer pair, supported by respiratory regulation of CO_2 and renal proton excretion, stabilizes extracellular fluid pH.
- A blood pH below 7.35 defines acidemia (acidosis), while a pH above 7.45 defines alkalemia (alkalosis).

Why other options are incorrect:

- Option A:** A pH range of 7.45 to 7.55 indicates physiological alkalemia, compromising neuromuscular stability and tissue perfusion.
- Option C:** A pH range of 7.15 to 7.25 represents severe uncompensated acidemia, which can induce cardiac depression and central nervous depression.
- Option D:** A pH range of 7.25 to 7.35 reflects mild to moderate acidosis below the normal physiological baseline.

Question #27 Key: (A)BIOLOGY
15. Inheritance / Variation & Genetics

In an X-linked recessive disease, an affected woman married to a normal man will have what perc...

CORE CONCEPT & DERIVATION

Female offspring inherit one paternal X chromosome and one maternal X chromosome; a phenotypically normal father always transmits a normal dominant X allele to all daughters.

Formula / Rule / Reaction:



Solution:

- An affected female possesses two recessive mutant alleles ($X^a X^a$), transmitting X^a to all progeny.
- The unaffected father possesses the dominant wild-type allele on his single X chromosome ($X^A Y$), transmitting X^A to 100% of his female offspring.
- Consequently, 100% of daughters are heterozygous carriers ($X^A X^a$) showing normal phenotype, meaning 0% (probability 0) are affected.

Why other options are incorrect:

- Option B:** 0.25 (25%) would only occur in specific autosomal recessive crosses involving two heterozygous carrier parents.
- Option C:** 0.5 (50%) would represent the proportion of affected daughters if the father were affected ($X^a Y$) and the mother were a carrier ($X^A X^a$).
- Option D:** 1 (100%) represents the proportion of affected sons ($X^a Y$), not daughters.

Question #28 Key: (A)BIOLOGY
04. Bioenergetics

The number of ATP used to produce one glucose molecule in the Calvin cycle is:

CORE CONCEPT & DERIVATION

Synthesis of one hexose molecule via the Calvin cycle requires six turns of the cycle to fix six molecules of carbon dioxide, consuming eighteen ATP and twelve NADPH.

Formula / Rule / Reaction:**Solution:**

- Each single turn of the Calvin cycle fixes one CO_2 molecule and requires 3 ATP (2 ATP for 3-phosphoglycerate phosphorylation and 1 ATP for RuBP regeneration) along with 2 NADPH.
- To assemble one net 6-carbon glucose molecule ($\text{C}_6\text{H}_{12}\text{O}_6$), six turns are required: $6 \times 3 \text{ ATP} = 18 \text{ ATP}$.

Why other options are incorrect:

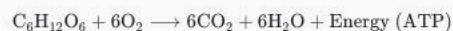
- Option B:** 27 ATP is an exaggerated count with no biochemical basis in the C3 photosynthetic pathway.
- Option C:** 9 ATP represents the energetic requirement for three turns of the Calvin cycle, which yields only one net triose phosphate (G3P) rather than a complete hexose.
- Option D:** 36 ATP represents the theoretical maximum yield of ATP derived from aerobic respiration of one glucose molecule, not its photosynthetic synthesis.

Question #29 Key: (C)BIOLOGY
02. Biomolecules

Which hexose is most important from a biological point of view?

CORE CONCEPT & DERIVATION

D-glucose is the central aldohexose monosaccharide serving as the universal respiratory substrate and primary energetic currency for cellular metabolism.

Formula / Rule / Reaction:**Solution:**

- Glucose directly enters the universal glycolytic pathway to yield pyruvate, driving substrate-level and oxidative phosphorylation.
- It serves as the circulating monosaccharide in blood and forms the repeating monomer of storage polymers such as glycogen and starch.

Why other options are incorrect:

- Option A:** Mannose is an epimer of glucose involved primarily in protein N-glycosylation rather than core energetic metabolism.
- Option B:** Fructose is a ketohexose that must be converted into glycolytic intermediates in the liver before complete catabolism.
- Option D:** Lactose is a disaccharide composed of glucose and galactose, not a hexose monosaccharide.

Question #30 Key: (D)BIOLOGY
15. Inheritance / Variation & Genetics*Chromosomes that are the same in males and females are called:***CORE CONCEPT & DERIVATION**

Autosomes are non-allosomal chromosomes that occur in morphologically identical homologous pairs in both biological sexes, regulating somatic genetic traits.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

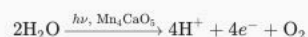
- Human somatic cells contain 23 pairs of chromosomes (46 total): 22 pairs of autosomes and 1 pair of sex chromosomes (allosomes).
- Because autosomes are identical in number, banding morphology, and gene loci between males and females, they constitute the shared non-sex chromosome pool.

Why other options are incorrect:

- Option A:** The X chromosome is an allosome present as two copies in typical females (XX) but only one copy in typical males (XY).
- Option B:** The Y chromosome is restricted to biological males, encoding male-determining factors such as the SRY gene.
- Option C:** Sex chromosomes (allosomes) differ structurally and numerically between males (XY) and females (XX).

Question #31 Key: (C)BIOLOGY
04. Bioenergetics*In the light reaction, water is used in:***CORE CONCEPT & DERIVATION**

Photolysis is the light-mediated catalytic splitting of water molecules by the oxygen-evolving complex of photosystem II to release protons, electrons, and molecular oxygen.

Formula / Rule / Reaction:**Solution:**

- During non-cyclic photophosphorylation, photon absorption excites the reaction center P_{680} , generating an electron deficit.
- Water undergoes photolytic cleavage at the luminal manganese cluster, providing replacement electrons to reduce P_{680}^+ while liberating O_2 as a byproduct.

Why other options are incorrect:

- Option A:** Reduction describes the gain of electrons; water donates electrons and is oxidized, whereas NADP^+ is reduced.
- Option B:** While the chemical cleavage of water is an oxidative process, the specific photochemical pathway in the thylakoid is termed photolysis.
- Option D:** Oxygenation denotes the addition of molecular oxygen to a compound without bond cleavage, which does not define water splitting.

Question #32 Key: (A)BIOLOGY
04. Bioenergetics*Light reaction takes place in which part of the chloroplast?***CORE CONCEPT & DERIVATION**

The light-dependent reactions occur within the thylakoid membranes and thylakoid lumen where light-harvesting pigment complexes, electron carriers, and ATP synthase reside.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Thylakoid membranes contain Photosystem I, Photosystem II, the cytochrome *b₆f* complex, and ATP synthase.
- Photon capture, electron transport, and the generation of a transmembrane proton motive force occur across this thylakoid membrane system.

Why other options are incorrect:

- Option B:** The stroma is the fluid phase containing soluble enzymes (such as RuBisCO) where the dark reactions (Calvin cycle) take place.
- Option C:** Lamellae (stromal lamellae) are interconnecting thylakoid channels, but "thylakoid" represents the comprehensive functional site.
- Option D:** Membrane is an imprecise descriptor; the outer and inner chloroplast envelope membranes do not harbor photosynthetic complexes.

Question #33 Key: (B)BIOLOGY
01. Cell*The outermost living boundary of the cell is:***CORE CONCEPT & DERIVATION**

The cell membrane (plasma membrane) is the outermost living, dynamic, semipermeable protoplasmic boundary of all biological cells.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- The plasma membrane consists of an amphipathic phospholipid bilayer embedded with functional transport proteins and signaling receptors.
- In plant, fungal, and bacterial cells, an extracellular cell wall lies exterior to the plasma membrane; however, the cell wall is an inert, non-living secretion.

Why other options are incorrect:

- Option A:** The cell wall is a rigid, non-living mechanical layer composed of cellulose, hemicellulose, and pectin.
- Option C:** Cytoplasm is the internal colloidal substance enclosed within the plasma membrane, not the cellular boundary.
- Option D:** The nuclear membrane is an internal double-membrane envelope that isolates the nucleus within the cytoplasm.

Question #34 Key: (D)BIOLOGY
12. Nervous Coordination*The sensation of pain is produced by:***CORE CONCEPT & DERIVATION**

Nociceptors are specialized sensory receptors comprising free nerve endings that respond selectively to noxious tissue-damaging stimuli to elicit pain.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Nociceptors are widely distributed in the skin, articular joints, periosteum, and visceral walls.
- They detect mechanical injury, extreme thermal changes, and chemical algogens (such as bradykinin, prostaglandins, and H^+), transmitting afferent pain impulses via A-delta and C fibers.

Why other options are incorrect:

- **Option A:** Thermoreceptors detect non-noxious changes in temperature (warmth and cold).
- **Option B:** Photoreceptors (rods and cones) transduce electromagnetic radiation in the retina for visual perception.
- **Option C:** Chemoreceptors monitor chemical concentrations such as partial pressures of arterial blood gases (pO_2 , pCO_2), pH, and taste/olfactory ligands.

Question #35 Key: (B)BIOLOGY
12. Nervous Coordination*The resting membrane potential is:***CORE CONCEPT & DERIVATION**

The resting membrane potential of a typical mammalian neuron is stabilized at approximately -70 mV, maintained by potassium leak channels and electrogenic sodium-potassium pumps.

Formula / Rule / Reaction:

$$V_m = \frac{RT}{F} \ln \left(\frac{P_K[K^+]_{out} + P_{Na}[Na^+]_{out} + P_{Cl}[Cl^-]_{in}}{P_K[K^+]_{in} + P_{Na}[Na^+]_{in} + P_{Cl}[Cl^-]_{out}} \right)$$

Solution:

- Neuronal resting membranes exhibit high permeability to potassium (K^+) via nongated leak channels, allowing K^+ to diffuse out down its chemical gradient.
- The Na^+/K^+ -ATPase actively expels three Na^+ ions for every two K^+ ions imported, establishing a stable interior-negative potential of -70 mV.

Why other options are incorrect:

- **Option A:** -60 mV is close to the threshold potential for firing action potentials in some specialized cardiac or smooth muscle tissues.
- **Option C:** -50 mV represents the typical neuronal threshold potential triggering the opening of voltage-gated Na^+ channels.
- **Option D:** -40 mV corresponds to the depolarized resting state of non-excitable cells or cardiac pacemaker nodal tissue.

Question #36 Key: (B)BIOLOGY
12. Nervous Coordination*Which neurotransmitter is present in the peripheral nervous system?***CORE CONCEPT & DERIVATION**

Acetylcholine is the primary classical neurotransmitter operating throughout the somatic and autonomic branches of the peripheral nervous system.

Formula / Rule / Reaction:**Solution:**

- Acetylcholine is released by all somatic motor neurons at skeletal neuromuscular junctions.
- It is also the neurotransmitter released by all preganglionic autonomic fibers, postganglionic parasympathetic fibers, and sympathetic fibers innervating sweat glands.

Why other options are incorrect:

- **Option A:** Epinephrine functions primarily as a circulating endocrine hormone released into systemic circulation by the adrenal medulla.
- **Option C:** Dopamine functions predominantly within central nervous system motor and reward pathways (e.g., substantia nigra, striatum).
- **Option D:** Serotonin acts as a major central neurotransmitter regulating mood and sleep, as well as an enteric paracrine signaling agent.

Question #37 Key: (C)CHEMISTRY
05. Liquids*Two ice blocks stick together due to:***CORE CONCEPT & DERIVATION**

When two ice blocks are pressed together, interfacial pressure melting followed by relief of pressure (regelation) enables water molecules to reform an integrated crystalline lattice via hydrogen bonding.

Formula / Rule / Reaction:**Solution:**

- Increased pressure at the contact interface lowers the local melting point of ice, producing a micro-film of liquid water.
- When the external pressure is released, the melting point reverts to 0°C, causing the water film to freeze immediately into a continuous structure knit by hydrogen bonds.

Why other options are incorrect:

- **Option A:** London dispersion forces are weak induced dipole-induced dipole interactions present in all molecules, but are insufficient to bond solid macroscopic ice blocks.
- **Option B:** Standard dipole-dipole interactions are much weaker than the specific directed hydrogen bonds that govern ice cohesion.
- **Option D:** Although dispersion forces exist, hydrogen bonding is the specific intermolecular force responsible for lattice cohesion and regelation.

Question #38 Key: (D)CHEMISTRY
08. Reaction Kinetics

The unit of rate constant is the same as for:

CORE CONCEPT & DERIVATION

For a zero-order reaction, the reaction rate is independent of reactant concentrations, making the dimensions of the rate constant identical to those of the reaction rate.

Formula / Rule / Reaction:

$$\text{Rate} = k[A]^0 = k \implies [k] = \text{mol} \cdot \text{dm}^{-3} \cdot \text{s}^{-1}$$

Solution:

- The general formula for the unit of a rate constant is $(\text{mol} \cdot \text{dm}^{-3})^{1-n} \cdot \text{s}^{-1}$, where n is the overall order of the reaction.
- Substituting $n = 0$ yields $\text{mol} \cdot \text{dm}^{-3} \cdot \text{s}^{-1}$, which is the exact unit of the reaction rate ($d[\text{conc}]/dt$).

Why other options are incorrect:

- Option A:** For a first-order reaction ($n = 1$), the unit of k is s^{-1} .
- Option B:** For a second-order reaction ($n = 2$), the unit of k is $\text{mol}^{-1} \cdot \text{dm}^3 \cdot \text{s}^{-1}$.
- Option C:** For a third-order reaction ($n = 3$), the unit of k is $\text{mol}^{-2} \cdot \text{dm}^6 \cdot \text{s}^{-1}$.

Question #39 Key: (B)CHEMISTRY
10. Electrochemistry

Reduction occurs at:

CORE CONCEPT & DERIVATION

By electrochemical convention, the cathode is the electrode where reduction (electron gain) takes place, irrespective of whether the cell is galvanic or electrolytic.

Formula / Rule / Reaction:**Solution:**

- Cations migrate toward the cathode where they accept electrons, undergoing reduction.
- Conversely, oxidation (loss of electrons) occurs at the anode in all electrochemical configurations.

Why other options are incorrect:

- Option A:** The anode is the electrode where oxidation (loss of electrons) occurs.
- Option C:** The salt bridge maintains electrical neutrality between half-cells via ion diffusion; it is not an electrode and supports no redox half-reactions.
- Option D:** Option B correctly identifies the electrode.

Question #40 Key: (A)CHEMISTRY
03. Chemical Bonding

Electron affinity decreases down the group due to:

CORE CONCEPT & DERIVATION

Descending a group in the periodic table adds electron shells, increasing the atomic radius and shielding effect, which weakens nuclear electrostatic attraction for an incoming electron.

Formula / Rule / Reaction:

$$\text{Electron Affinity} \propto \frac{Z_{\text{eff}}}{r}$$

Solution:

- As the principal quantum number increases down a group, the distance between the nucleus and the valence shell expands.
- The shielding effect of intervening core electrons offsets the increase in nuclear charge, resulting in a diminished effective nuclear grip on an added electron and decreasing electron affinity.

Why other options are incorrect:

- Option B:** Atomic radius increases, rather than decreases, as new electronic shells are added down a group.
- Option C:** Electronegativity decreases down a group due to increased bond lengths and shielding.
- Option D:** Only Option A is factually correct.

Question #41 Key: (B)

CHEMISTRY
11. S & P Block Elements

Which one is least ionic?

CORE CONCEPT & DERIVATION

According to Fajan's rules, cations with higher charge density exert greater polarizing power on the electron cloud of an anion, introducing significant covalent character.

Formula / Rule / Reaction:

$$\text{Polarizing Power} \propto \frac{\text{Ionic Charge}}{\text{Ionic Radius}}$$

Solution:

- The aluminum cation in AlCl_3 carries a high charge (+3) and a small ionic radius, giving it the highest charge density among the group.
- This strong polarizing power distorts the electron cloud of the chloride anions, imparting covalent character and making AlCl_3 the least ionic (most covalent) chloride listed.

Why other options are incorrect:

- Option A:** NaCl contains the univalent Na^+ ion with lower charge density, exhibiting pronounced ionic character.
- Option C:** MgCl_2 contains the divalent Mg^{2+} ion, which is less polarizing than trivalent Al^{3+} .
- Option D:** KCl contains the large K^+ ion with very low charge density, making it the most ionic compound in this set.

Question #42 Key: (A)

CHEMISTRY
06. Solids

Diamond is:

CORE CONCEPT & DERIVATION

Diamond is a giant network covalent crystal consisting of carbon atoms bonded to four adjacent carbon atoms via localized sp^3 tetrahedral covalent bonds.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- In diamond, each carbon atom is covalently linked to four other carbons in an infinite three-dimensional tetrahedral lattice.
- Because the entire crystal is held together by continuous, strong covalent bonds rather than intermolecular forces, diamond is classified as a macromolecular (network) covalent solid.

Why other options are incorrect:

- Option B:** Molecular solids (such as dry ice or iodine) consist of discrete molecules held together by weak van der Waals forces.
- Option C:** Metallic solids are arrays of metal cations enveloped in a sea of delocalized valence electrons.
- Option D:** Ionic solids (such as sodium chloride) consist of alternating positive and negative ions held by electrostatic lattice forces.

Question #43 Key: (B)

CHEMISTRY
11. S & P Block Elements

What is the most common gas in the environment?

CORE CONCEPT & DERIVATION

Molecular nitrogen (N_2) is the most abundant chemical species in Earth's atmosphere by both volume and mass.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Dry atmospheric air comprises approximately 78.08% nitrogen (N_2) by volume.
- Oxygen makes up roughly 20.95%, argon comprises 0.93%, and carbon dioxide accounts for roughly 0.04%.

Why other options are incorrect:

- Option A:** Oxygen is the second most abundant atmospheric gas at approximately 21% by volume.
- Option C:** Carbon dioxide is a trace atmospheric gas constituting approximately 0.04% (420 ppm) of dry air.
- Option D:** Helium is a noble gas present in trace quantities (around 5.2 ppm).

Question #44 Key: (A)CHEMISTRY
03. Chemical Bonding*Which one of the following has greater bond energy?***CORE CONCEPT & DERIVATION**

Bond dissociation energy is inversely proportional to internuclear bond length; smaller bonded atoms produce shorter, stronger bonds due to maximal orbital overlap.

Formula / Rule / Reaction:

Bond Dissociation Energies: HF ($568 \text{ kJ} \cdot \text{mol}^{-1}$) > HCl (431) > HBr (366) > HI (299)

Solution:

- Fluorine has the smallest atomic radius among the halogens, resulting in the shortest internuclear bond length for the $\text{H} - \text{F}$ covalent bond.
- The substantial electronegativity difference creates significant ionic resonance stabilization, giving HF the highest bond dissociation energy ($568 \text{ kJ} \cdot \text{mol}^{-1}$).

Why other options are incorrect:

- Option B:** The $\text{H} - \text{Cl}$ bond has a longer internuclear distance, yielding an intermediate bond energy of $431 \text{ kJ} \cdot \text{mol}^{-1}$.
- Option C:** The $\text{H} - \text{Br}$ bond has a bond energy of $366 \text{ kJ} \cdot \text{mol}^{-1}$.
- Option D:** The $\text{H} - \text{I}$ bond is the longest and weakest among the hydrogen halides, with a bond energy of $299 \text{ kJ} \cdot \text{mol}^{-1}$.

Question #45 Key: (C)CHEMISTRY
10. Electrochemistry*The oxidation number of an element in free state is:***CORE CONCEPT & DERIVATION**

By definition and convention in redox chemistry, the oxidation state of any atom in its uncombined elemental state is zero.

Formula / Rule / Reaction:

$$\text{Oxidation Number of Uncombined Element} = 0$$

Solution:

- An element in its free or elemental form (e.g., Na , Fe , H_2 , O_2 , P_4) has not transferred or unevenly shared electrons with atoms of different electronegativity.
- Because there is no net redistribution of electron density relative to the neutral atom, its oxidation number is zero.

Why other options are incorrect:

- Option A:** +1 is the characteristic oxidation state of alkali metals in chemical compounds.
- Option B:** +2 is the characteristic oxidation state of alkaline earth metals in chemical compounds.
- Option D:** -1 is the typical oxidation state of halogens in halides.

Question #46 Key: (A)CHEMISTRY
13. Fundamental Principles of Organic Chemistry*Homocyclic hydrocarbons are further divided into:***CORE CONCEPT & DERIVATION**

Homocyclic (carbocyclic) compounds contain closed rings composed solely of carbon atoms, which are classified into non-aromatic alicyclic and conjugated aromatic systems.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Homocyclic (or carbocyclic) ring systems contain only ring carbons without heteroatoms.
- They are subdivided into alicyclic compounds (which resemble aliphatic hydrocarbons in behavior, such as cyclobutane or cyclohexane) and aromatic compounds (which possess delocalized π -electron systems satisfying Hückel's $4n + 2$ rule, such as benzene).

Why other options are incorrect:

- Option B:** Carbocyclic is synonymous with homocyclic, and heterocyclic compounds contain at least one heteroatom (such as N, O, or S) in the ring framework.
- Option C:** Acyclic refers to open-chain aliphatic compounds, which do not contain ring structures.
- Option D:** Heterocyclic compounds form an entirely separate primary classification alongside homocyclic compounds.

Question #47 Key: (D)

CHEMISTRY
03. Chemical Bonding

Which contains [Formula] hybridization?

CORE CONCEPT & DERIVATION

Orbital hybridization is determined by the steric number of sigma bonds and lone pairs surrounding the central carbon atom; sp^2 hybridization requires three hybrid orbitals oriented at 120° .

Formula / Rule / Reaction:

$$\text{Steric Number} = (\text{Number of } \sigma \text{ bonds}) + (\text{Number of lone pairs}) = 3 \implies sp^2$$

Solution:

- Methane (CH_4) possesses four C – H σ bonds, yielding an sp^3 tetrahedral geometry.
- Ethane (C_2H_6) contains carbon atoms bonded to four other atoms each, forming sp^3 hybridized tetrahedral centers.
- Alkynes (e.g., ethyne) possess a carbon-carbon triple bond composed of one σ bond and two π bonds, resulting in sp linear hybridization. Consequently, none of the listed options contain sp^2 hybridization.

Why other options are incorrect:

- **Option A:** Methane has four single σ bonds and exhibits sp^3 hybridization.
- **Option B:** Both carbon atoms in ethane form four single bonds and are sp^3 hybridized.
- **Option C:** Alkynes possess triply bonded carbons with two σ bonds, which is characteristic of sp hybridization.

Question #48 Key: (B)

CHEMISTRY
13. Fundamental Principles of Organic Chemistry

Geometric isomerism is shown by:

CORE CONCEPT & DERIVATION

Geometric (cis-trans) isomerism arises from restricted rotation about a rigid carbon-carbon double bond when each unsaturated carbon atom bears two different substituent groups.

Formula / Rule / Reaction:

$$\text{Condition: } R_1R_2C = CR_3R_4 \quad (\text{where } R_1 \neq R_2 \text{ and } R_3 \neq R_4)$$

Solution:

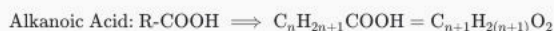
- The carbon-carbon double bond in alkenes consists of a strong σ bond and an overlapping π bond that prevents free rotation at room temperature without breaking the π overlap.
- When each double-bonded carbon carries two non-identical ligands, distinct spatial configurations (cis and trans diastereomers) exist.

Why other options are incorrect:

- **Option A:** Alkanes possess single carbon-carbon σ bonds capable of free axial rotation, producing conformational rather than geometric isomers.
- **Option C:** Alkynes exhibit a linear geometry (180°) about the triple bond with only one substituent per carbon, precluding cis-trans spatial distinction.
- **Option D:** Because alkanes and alkynes cannot exhibit geometric isomerism, this collective option is invalid.

Question #49 Key: (C)CHEMISTRY
13. Fundamental Principles of Organic Chemistry*[Formula]* is the general molecular formula of:**CORE CONCEPT & DERIVATION**

Monocarboxylic acids and their functional group isomers, aliphatic esters, contain one carbonyl double bond and two oxygen atoms, adhering to the homologous formula $C_nH_{2n}O_2$.

Formula / Rule / Reaction:**Solution:**

- A saturated open-chain monocarboxylic acid contains one carbon-oxygen double bond (one degree of unsaturation) and one single carbon-oxygen bond.
- For example, ethanoic acid (CH_3COOH) has 2 carbons, 4 hydrogens, and 2 oxygens, precisely satisfying $C_nH_{2n}O_2$ where $n = 2$.

Why other options are incorrect:

- Option A:** Saturated monohydric aliphatic alcohols conform to the general formula $C_nH_{2n+2}O$.
- Option B:** Saturated aliphatic ketones possess one oxygen atom and follow the general formula $C_nH_{2n}O$.
- Option D:** Dialkyl ethers are functional isomers of alcohols and conform to $C_nH_{2n+2}O$.

Question #50 Key: (B)CHEMISTRY
17. Aldehydes & KetonesConcentrated 50% *[Formula]* is used in:**CORE CONCEPT & DERIVATION**

The Cannizzaro reaction is a base-catalyzed disproportionation of aldehydes lacking α -hydrogens, requiring strong concentrated alkaline conditions (50% aqueous or alcoholic NaOH).

Formula / Rule / Reaction:**Solution:**

- Aldehydes with no α -hydrogen atoms (such as formaldehyde and benzaldehyde) cannot form enolate nucleophiles.
- When heated with 50% concentrated NaOH, one molecule undergoes reduction to an alcohol while another molecule undergoes simultaneous oxidation to a carboxylate salt via intermolecular hydride shift.

Why other options are incorrect:

- Option A:** Aldol condensation uses aldehydes containing α -hydrogens in the presence of dilute base (such as 10% NaOH).
- Option C:** Clemmensen reduction utilizes zinc amalgam ($Zn[Hg]$) in concentrated hydrochloric acid (HCl), an acidic medium.
- Option D:** Wolff-Kishner reduction employs hydrazine (NH_2NH_2) with KOH in high-boiling ethylene glycol at elevated temperatures.

Question #51 Key: (C)

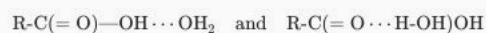
CHEMISTRY
05. Liquids

Carboxylic acids are soluble in water due to:

CORE CONCEPT & DERIVATION

Low molecular weight carboxylic acids dissolve in water because the highly polarized hydroxyl and carbonyl groups of the carboxyl moiety form intermolecular hydrogen bonds with water molecules.

Formula / Rule / Reaction:



Solution:

- The carboxyl group ($-\text{COOH}$) contains both a hydrogen-bond donor (the polarized $-\text{OH}$ proton) and hydrogen-bond acceptors (carbonyl and hydroxyl oxygens).
- These sites engage in extensive hydrogen-bonding networks with solvent water molecules, overcoming solute-solute cohesive forces in lower aliphatic acids (up to 4 carbons).

Why other options are incorrect:

- Option A:** Dipole-dipole forces contribute to overall polarity, but the high aqueous solubility of carboxylic acids is governed by hydrogen bonding.
- Option B:** London dispersion forces are weak non-specific attractive forces dominant between non-polar alkyl chains, which oppose water solubility.
- Option D:** Dissolution is a physical solvation phenomenon governed by non-covalent interactions, not the formation of solute-solvent covalent bonds.

Question #52 Key: (C)

CHEMISTRY
18. Carboxylic Acids

Esterification occurs in the presence of:

CORE CONCEPT & DERIVATION

Fischer esterification is an acid-catalyzed condensation reaction between a carboxylic acid and an alcohol that yields an ester and water.

Formula / Rule / Reaction:



Solution:

- Protonation of the carboxylic acid carbonyl oxygen by a strong mineral acid catalyst (such as concentrated H_2SO_4) activates the carbonyl carbon toward nucleophilic attack.
- The alcohol attacks the activated carbonyl carbon to form a tetrahedral intermediate, which eliminates water to produce the ester.

Why other options are incorrect:

- Option A:** Combining aldehydes and ketones under basic conditions yields mixed aldol condensation products, not esters.
- Option B:** Alcohols react with ketones under acidic conditions to form hemiketals and ketals, not esters.
- Option D:** Carboxylic acids do not condense with aldehydes to generate ester linkages.

Question #53 Key: (B)

CHEMISTRY
18. Carboxylic Acids

Benzene can be prepared from sodium benzoate by reaction with:

CORE CONCEPT & DERIVATION

Decarboxylation of the sodium salt of an aromatic carboxylic acid by heating with soda lime (a dry mixture of NaOH and CaO) eliminates the carboxylate group to yield benzene.

Formula / Rule / Reaction:**Solution:**

- Heating sodium benzoate with soda lime promotes nucleophilic attack by hydroxide on the carbonyl carbon.
- This causes heterolytic cleavage of the phenyl-carbonyl bond, releasing carbon dioxide as sodium carbonate (Na_2CO_3) and protonating the phenyl carbanion to yield benzene.

Why other options are incorrect:

- **Option A:** Anhydrous AlCl_3 is a Lewis acid catalyst used in electrophilic aromatic substitutions (Friedel-Crafts reactions), not decarboxylation.
- **Option C:** Chlorobenzene is an aryl halide that does not induce decarboxylation in benzoate salts.
- **Option D:** Cumene (isopropylbenzene) is an alkylbenzene intermediate used industrially for phenol synthesis, not a decarboxylating reagent.

Question #54 Key: (B)

CHEMISTRY
01. Stoichiometry

Empirical formula is related to molecular formula by:

CORE CONCEPT & DERIVATION

The molecular formula of a compound is a whole-number integer multiple (n) of its simplest integer-ratio empirical formula.

Formula / Rule / Reaction:

$$\text{Molecular Formula} = n \times (\text{Empirical Formula}), \quad \text{where } n = \frac{\text{Molecular Mass}}{\text{Empirical Formula Mass}}$$

Solution:

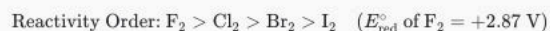
- The empirical formula represents the relative simplest ratio of atoms present in a chemical compound.
- The molecular formula indicates the exact number of atoms of each element in one discrete molecule, obtained by multiplying each empirical subscript by the integer factor n .

Why other options are incorrect:

- **Option A:** Dividing the empirical formula by n would yield fractional subscripts, which is algebraically inverted and chemically meaningless.
- **Option C:** Introducing an extra factor of 2 doubles the true stoichiometric molecular mass.
- **Option D:** Chemical formulas cannot be summed additively with scalar multipliers; this expression is mathematically unsound.

Question #55 Key: (A)CHEMISTRY
11. S & P Block Elements*Which one is more reactive among halogens?***CORE CONCEPT & DERIVATION**

Elemental fluorine (F_2) is the most chemically reactive halogen due to its exceptionally low bond dissociation energy, high electronegativity, and high standard reduction potential.

Formula / Rule / Reaction:**Solution:**

- The $F - F$ covalent bond is unusually weak ($158 \text{ kJ} \cdot \text{mol}^{-1}$) due to electrostatic repulsion between the non-bonding lone pairs crowded within small fluorine atoms.
- Combined with its high electron affinity and high hydration energy of the resulting fluoride ion, fluorine reacts rapidly and exothermically with nearly all elements.

Why other options are incorrect:

- Option B:** Chlorine has a higher bond dissociation energy ($242 \text{ kJ} \cdot \text{mol}^{-1}$) and a lower reduction potential ($+1.36 \text{ V}$), making it less reactive than fluorine.
- Option C:** Bromine is a liquid with lower oxidizing ability and electronegativity than chlorine and fluorine.
- Option D:** Iodine has the largest atomic radius, weakest oxidizing capacity, and lowest reactivity among stable halogens.

Question #56 Key: (B)CHEMISTRY
09. Thermochemistry*One calorie is equal to:***CORE CONCEPT & DERIVATION**

The thermochemical calorie is defined as the amount of thermal energy required to raise the temperature of one gram of pure water by one degree Celsius, equivalent to 4.184 joules.

Formula / Rule / Reaction:

$$1 \text{ cal} = 4.184 \text{ J} \approx 4.18 \text{ J}$$

Solution:

- The joule (J) is the SI unit of energy, while the calorie is a historical metric unit of thermal capacity.
- By international agreement, 1 calorie corresponds to 4.184 joules, commonly rounded in provincial textbook problem sets to 4.18 J.

Why other options are incorrect:

- Option A:** 4.18 kJ represents 1000 calories (one kilocalorie or nutritional Calorie), three orders of magnitude larger than a calorie.
- Option C:** 18 J is a distractor derived from numeric confusion with the decimal fraction in 4.18.
- Option D:** 18 kJ has no basis in metric energy conversion.

Question #57 Key: (C)CHEMISTRY
09. Thermochemistry

The net enthalpy change in a chemical reaction is the same whether it is brought about in two o...

CORE CONCEPT & DERIVATION

Hess's Law of Constant Heat Summation states that the total enthalpy change for a chemical reaction is independent of the pathway taken, depending exclusively on initial and final thermodynamic states.

Formula / Rule / Reaction:

$$\Delta H_{\text{net}} = \Delta H_1 + \Delta H_2 + \Delta H_3 + \dots = \sum \Delta H_{\text{steps}}$$

Solution:

- Enthalpy (H) is a thermodynamic state function; its change (ΔH) depends only on the state of the reactants and products, not on the reaction mechanism.
- Consequently, the net heat absorbed or evolved across a multi-step reaction equals the algebraic sum of the enthalpy changes of the individual intermediate steps.

Why other options are incorrect:

- Option A:** Joule's law defines the rate at which electrical resistance dissipates energy as heat ($P = I^2 R$) or the invariance of ideal gas internal energy with volume.
- Option B:** The law of conservation of energy is the first law of thermodynamics, representing the overarching concept from which Hess's law is derived.
- Option D:** Henry's law states that the mass of a dissolved gas in a liquid is directly proportional to its equilibrium partial pressure.

Question #58 Key: (A)CHEMISTRY
08. Reaction Kinetics

Which is not true about the rate of reaction?

CORE CONCEPT & DERIVATION

According to chemical kinetics, the instantaneous rate of a chemical reaction generally depends directly on the molar concentrations of the reacting species raised to powers equal to their reaction orders.

Formula / Rule / Reaction:

$$\text{Rate} = k[A]^m[B]^n$$

Solution:

- As reactant concentrations increase, collision frequency between reacting molecules rises, which elevates reaction velocity.
- Therefore, stating that the reaction rate is independent of reactant concentration is false for all reactions except zero-order systems.

Why other options are incorrect:

- Option B:** This statement is true; reaction rates increase with temperature in accordance with the Arrhenius equation ($k = Ae^{-E_a/RT}$).
- Option C:** The reaction order is a kinetic parameter, whereas concentration and temperature directly dictate the observable rate of consumption.
- Option D:** Because Option A is a false statement, this collective distractor is incorrect.

Question #59 Key: (B)

CHEMISTRY
11. S & P Block Elements

Which one is an s-block element?

CORE CONCEPT & DERIVATION

Elements whose differentiating (last) valence electron enters an *s*-subshell are classified as *s*-block elements, encompassing Groups 1 (alkali metals) and 2 (alkaline earth metals).

Formula / Rule / Reaction:



Solution:

- Potassium (K, $Z = 19$) possesses a single valence electron in its outermost *4s* subshell, identifying it as an alkali metal in the *s*-block.
- Note on board errata: Calcium (Ca, $Z = 20$, $[Ar] 4s^2$) is also an authentic *s*-block element. This item represents a recognized board key defect where Potassium (K) was designated as the official key while Boron is *p*-block and cumene is an organic compound.

Why other options are incorrect:

- Option A:** Boron (B, $Z = 5$) has the ground-state electron configuration $1s^2 2s^2 2p^1$, placing it in the *p*-block.
- Option C:** Calcium is also an *s*-block element (Group 2); however, official board grading keyed Option B.
- Option D:** Cumene (isopropylbenzene, C_9H_{12}) is an aromatic hydrocarbon molecule, not a chemical element.

Question #60 Key: (C)

CHEMISTRY
03. Chemical Bonding

Bond angle is [Formula] in:

CORE CONCEPT & DERIVATION

Molecules with sp^2 hybridized central carbon atoms adopt trigonal planar geometries with ideal bond angles of 120° .

Formula / Rule / Reaction:



Solution:

- In ethene (C_2H_4), each carbon atom forms three σ bonds (two with hydrogen and one with the adjacent carbon) using three sp^2 hybrid orbitals.
- To minimize electron repulsion according to VSEPR theory, these three coplanar orbitals are directed toward the corners of an equilateral triangle at 120° angles.

Why other options are incorrect:

- Option A:** Ethane possesses sp^3 hybridized tetrahedral carbon atoms with bond angles of 109.5° .
- Option B:** Ethyne contains sp hybridized linear carbons with bond angles of 180° .
- Option D:** Cyclopropane possesses a planar three-membered ring forced into severe ring strain with internal C – C – C bond angles compressed to 60° .

Question #61 Key: (D)PHYSICS
02. Force & Motion*In a perfectly elastic collision:***CORE CONCEPT & DERIVATION**

A perfectly elastic collision is an interaction in an isolated system where no mechanical kinetic energy is converted into non-conservative forms such as heat, sound, or permanent deformation.

Formula / Rule / Reaction:

$$\sum \vec{p}_i = \sum \vec{p}_f, \quad \sum KE_i = \sum KE_f, \quad \text{and} \quad E_{\text{total}} = \text{constant}$$

Solution:

- In any isolated system free from external forces, linear momentum is conserved due to Newton's third law.
- By definition of an elastic collision, kinetic energy is fully conserved across the impact, and total energy is universally conserved in all physical processes.

Why other options are incorrect:

- **Option A:** Momentum is conserved, but kinetic energy and total energy are also conserved, rendering this option incomplete.
- **Option B:** Total energy is conserved, but momentum and kinetic energy are conserved as well.
- **Option C:** Kinetic energy cannot be conserved without simultaneous conservation of momentum.

Question #62 Key: (A)PHYSICS
02. Force & Motion*The slope of a displacement-time graph is:***CORE CONCEPT & DERIVATION**

Velocity is the time rate of change of displacement; graphically, this equals the slope of the tangent to the curve on a displacement versus time plot.

Formula / Rule / Reaction:

$$\text{Slope} = \frac{\Delta d}{\Delta t} = \frac{dd}{dt} = v$$

Solution:

- The vertical axis of the graph represents displacement (d), while the horizontal axis represents time (t).
- The slope is calculated as the ratio of change in vertical coordinates to horizontal coordinates ($\Delta d / \Delta t$), which defines instantaneous velocity.

Why other options are incorrect:

- **Option B:** Displacement is the coordinate value on the vertical axis, not the gradient of the curve.
- **Option C:** Acceleration is the slope of a velocity-time graph ($\Delta v / \Delta t$), which represents the second derivative of displacement.
- **Option D:** Distance is a scalar path length, whereas the slope of a scalar distance-time plot yields speed.

Question #63 Key: (B)PHYSICS
04. Rotational & Circular Motion

An object moving along a circular path of radius [Formula] covers a distance of [Formula] along...

CORE CONCEPT & DERIVATION

Angular displacement (θ) is the ratio of arc length (s) traversed along a circle to the radius (r) of the circular orbit.

Formula / Rule / Reaction:

$$s = r\theta \implies \theta = \frac{s}{r}$$

Solution:

- The linear path distance covered along the circumference is $s = 2\text{ m}$.
- The radius of the circular path is $r = 1\text{ m}$.
- Calculating angular displacement:

$$\theta = \frac{2\text{ m}}{1\text{ m}} = 2\text{ radians}$$

Why other options are incorrect:

- Option A:** $\frac{1}{2}$ radian results from inverting the relationship (r/s).
- Option C:** 3 radians is a spurious arithmetic distractor.
- Option D:** $\frac{2}{3}$ radian has no physical basis in the given orbital dimensions.

Question #64 Key: (B)PHYSICS
05. Waves

Speed of sound is [Formula] at [Formula]. What will be its value at [Formula]?

CORE CONCEPT & DERIVATION

The velocity of sound in air increases linearly with temperature near 0°C by approximately 0.61 m/s for every degree Celsius rise in temperature.

Formula / Rule / Reaction:

$$v_t = v_0 + 0.61t$$

Solution:

- Given base speed $v_0 = 332\text{ m/s}$ at $t = 0^\circ\text{C}$ and final temperature $t = 10^\circ\text{C}$.
- Calculating the temperature correction:
 $\Delta v = 0.61 \times 10 = 6.1\text{ m/s}$
- Computing the corrected sound velocity:
 $v_{10} = 332 + 6.1 = 338.1\text{ m/s}$

Why other options are incorrect:

- Option A:** 332 m/s represents the speed of sound at 0°C without temperature adjustment.
- Option C:** 332.61 m/s corresponds to an increase for only 1°C rather than 10°C .
- Option D:** 334.1 m/s is an arithmetic error using an incorrect coefficient of $0.21\text{ m/s} \cdot ^\circ\text{C}^{-1}$.

Question #65 Key: (C)PHYSICS
07. Thermodynamics

In molar specific heat, the equation [Formula] shows that:

CORE CONCEPT & DERIVATION

Molar heat capacity at constant pressure (C_p) exceeds molar heat capacity at constant volume (C_v) because heating at constant pressure requires extra energy to perform boundary expansion work.

Formula / Rule / Reaction:

$$C_p - C_v = R \implies C_p = C_v + R$$

Solution:

- At constant volume, all supplied heat increases the system internal energy ($dQ_v = dU$).
- At constant pressure, gas expansion against surrounding pressure consumes work ($dW = P dV$), meaning extra heat must be supplied: $dQ_p = dU + P dV$.
- Because the universal gas constant is positive ($R > 0$), C_p is strictly greater than C_v .

Why other options are incorrect:

- **Option A:** $C_p < C_v$ would require a negative gas constant ($R < 0$), which is unphysical.
- **Option B:** $C_p = C_v$ applies only to incompressible condensed phases where thermal expansion work is negligible.
- **Option D:** Stating $C_p = \text{Constant}$ does not express the inequality relationship shown by Mayer's equation.

Question #66 Key: (C)PHYSICS
07. Thermodynamics

The thermodynamic process during which volume of the system remains constant is:

CORE CONCEPT & DERIVATION

An isochoric (isovolumetric) process is a thermodynamic transformation conducted at constant volume, meaning no boundary displacement work is performed.

Formula / Rule / Reaction:

$$\Delta V = 0 \implies W = \int P dV = 0$$

Solution:

- By definition, an isochoric process occurs within a rigid non-deformable boundary where $V = \text{constant}$.
- According to the first law of thermodynamics, since work $W = P \Delta V = 0$, all heat transferred changes internal energy: $\Delta Q = \Delta U$.

Why other options are incorrect:

- **Option A:** An isothermal process is one where the temperature remains constant ($\Delta T = 0$).
- **Option B:** An isobaric process is one where system pressure remains constant ($\Delta P = 0$).
- **Option D:** An adiabatic process is one where no heat enters or leaves the system ($Q = 0$).

Question #67 Key: (A)PHYSICS
08. Electrostatics

If two capacitors of capacitance [Formula] and [Formula] are connected in parallel, the equivalent...

CORE CONCEPT & DERIVATION

When capacitors are connected in parallel, the total charge stored is the sum of charges across individual branches, making the equivalent capacitance equal to the algebraic sum of individual capacitances.

Formula / Rule / Reaction:

$$C_{eq} = C_1 + C_2 + C_3 + \dots + C_n$$

Solution:

- Given branch capacitances: $C_1 = 2 \mu\text{F}$ and $C_2 = 6 \mu\text{F}$.
- In a parallel circuit, both capacitors experience the same potential difference V .
- Calculating equivalent capacitance:

$$C_{eq} = 2 \mu\text{F} + 6 \mu\text{F} = 8 \mu\text{F}$$

Why other options are incorrect:

- Option B:** $\frac{3}{2} \mu\text{F}$ ($1.5 \mu\text{F}$) is the equivalent capacitance if the two capacitors were connected in series: $C_{eq} = \frac{2 \times 6}{2+6} = 1.5 \mu\text{F}$.
- Option C:** $4 \mu\text{F}$ is the arithmetic difference between the two values, which has no circuit basis.
- Option D:** $12 \mu\text{F}$ is the product of the two values.

Question #68 Key: (C)PHYSICS
09. Current Electricity

Power transfer will be maximum when:

CORE CONCEPT & DERIVATION

According to the Maximum Power Transfer Theorem, an electric power source transfers maximum power to an external load when the load resistance equals the internal resistance of the source.

Formula / Rule / Reaction:

$$P_L = I^2 R = \left(\frac{E}{R+r} \right)^2 R \Rightarrow \frac{dP_L}{dR} = 0 \Rightarrow R = r$$

Solution:

- Differentiating load power P_L with respect to load resistance R and equating to zero establishes the condition for maximum power dissipation.
- When $R = r$, internal power dissipation inside the source equals power delivered to the load, achieving maximum transfer efficiency of 50%.

Why other options are incorrect:

- Option A:** When $R > r$, circuit current drops, reducing total power dissipated across the load.
- Option B:** When $R < r$, internal resistance dissipates the majority of the source energy as heat within the source.
- Option D:** $R = \frac{1}{r}$ is dimensionally inconsistent because resistance cannot equal conductance.

Question #69 Key: (D)PHYSICS
09. Current Electricity

A wire is stretched so that its radius of cross-section becomes half. Then resistance of the wire...

CORE CONCEPT & DERIVATION

When a wire is stretched, its total volume remains constant; halving the cross-sectional radius reduces the area by a factor of 4 and quadruples the length, compounding resistance sixteen-fold.

Formula / Rule / Reaction:

$$R = \rho \frac{L}{A} \quad \text{and} \quad \text{Volume } V = A \times L = \pi r^2 L = \text{constant} \implies R \propto \frac{1}{r^4}$$

Solution:

- When stretched to half radius, the new cross-sectional area becomes:

$$A' = \pi(r')^2 = \pi\left(\frac{r}{2}\right)^2 = \frac{A}{4}$$

- Because volume is conserved ($V = A \cdot L = A' \cdot L'$), the length increases fourfold:

$$L' = 4L$$

- Calculating new resistance:

$$R' = \rho \frac{L'}{A'} = \rho \frac{4L}{A/4} = 16\left(\rho \frac{L}{A}\right) = 16R$$

Why other options are incorrect:

- Option A:** $4R$ accounts only for the length increase or area reduction independently, ignoring volume conservation.
- Option B:** $\frac{R}{4}$ represents a resistance decrease, which contradicts the elongation and thinning of the wire.
- Option C:** $8R$ is an arithmetic error confusing cubic with fourth-power geometric scaling.

Question #70 Key: (C)PHYSICS
10. Electromagnetism

When a charged particle enters a magnetic field parallel to the field lines, it:

CORE CONCEPT & DERIVATION

The magnetic Lorentz force on a moving charge is proportional to the vector cross product of its velocity and the magnetic flux density; when velocity is parallel to the magnetic field, the net force is zero.

Formula / Rule / Reaction:

$$\vec{F} = q(\vec{v} \times \vec{B}) \implies F = qvB \sin \theta = qvB \sin(0^\circ) = 0$$

Solution:

- Because the charged particle travels parallel to the magnetic flux lines, the angle of entry is $\theta = 0^\circ$.
- Substituting $\sin(0^\circ) = 0$ yields zero magnetic Lorentz force, meaning no transverse acceleration acts on the particle.
- By Newton's first law, the particle continues along its original linear trajectory at constant velocity without deflection.

Why other options are incorrect:

- Option A:** Deflection northward requires an unbalanced perpendicular Lorentz force vector.
- Option B:** Deflection southward similarly requires a non-zero transverse magnetic deflecting force.
- Option D:** Circular motion requires a continuous centripetal force, which occurs only when entry is perpendicular ($\theta = 90^\circ$).

Question #71 Key: (A)PHYSICS
10. Electromagnetism

Magnetic flux is maximum when the angle between the magnetic field and the vector area is:

CORE CONCEPT & DERIVATION

Magnetic flux measures the total number of magnetic field lines penetrating a surface, quantified as the scalar dot product of the magnetic field vector and the area vector.

Formula / Rule / Reaction:

$$\Phi_B = \vec{B} \cdot \vec{A} = BA \cos \theta$$

Solution:

- The vector area $\vec{A}$ is defined normal (perpendicular) to the planar surface.
- When the magnetic field $\vec{B}$ is aligned parallel to the normal vector area $\vec{A}$, the angle is $\theta = 0^\circ$.
- Because $\cos(0^\circ) = 1$ (its maximum algebraic value), magnetic flux reaches its absolute peak: $\Phi_{B,\max} = BA$.

Why other options are incorrect:

- **Option B:** At $\theta = 45^\circ$, $\cos(45^\circ) \approx 0.707$, yielding roughly 71% of maximum flux.
- **Option C:** At $\theta = 90^\circ$, $\cos(90^\circ) = 0$, producing zero magnetic flux because field lines graze the surface plane without crossing.
- **Option D:** At $\theta = 180^\circ$, $\cos(180^\circ) = -1$, which represents maximum flux in the reverse direction rather than the standard positive maximum.

Question #72 Key: (B)PHYSICS
11. Electromagnetic Induction

The domestic electricity supply in Pakistan has a frequency of:

CORE CONCEPT & DERIVATION

National utility distribution grids deliver single-phase alternating current at standardized parameters; Pakistan operates under the 230 V, 50 Hz utility standard.

Formula / Rule / Reaction:

$$f = 50 \text{ Hz} \implies T = \frac{1}{f} = \frac{1}{50} = 0.02 \text{ s} = 20 \text{ ms}$$

Solution:

- The national power grid follows International Electrotechnical Commission (IEC) technical standards.
- Domestic wall outlets provide alternating voltage completing 50 full sinusoidal cycles per second, corresponding to a frequency of 50 Hz.

Why other options are incorrect:

- **Option A:** 70 Hz is an arbitrary value not used in standard commercial power transmission grids.
- **Option C:** 100 Hz is the ripple frequency of full-wave rectified 50 Hz AC, not the line transmission frequency.
- **Option D:** 30 Hz is not utilized in utility distribution grids.

Question #73 Key: (C)PHYSICS
11. Electromagnetic Induction

The device that increases or decreases the electromotive force (emf) is called a:

CORE CONCEPT & DERIVATION

A transformer is a static electromagnetic machine that transforms alternating voltages and currents to higher or lower levels through mutual induction across magnetically coupled windings.

Formula / Rule / Reaction:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

Solution:

- A transformer consists of two insulated copper coils (primary and secondary) wound around a common laminated soft-iron core.
- Alternating current in the primary winding creates a time-varying magnetic flux that links with the secondary winding, inducing a stepped-up or stepped-down alternating emf determined by the turns ratio.

Why other options are incorrect:

- **Option A:** An AC generator converts mechanical energy into alternating electrical energy through electromagnetic induction.
- **Option B:** An electric motor converts electrical energy into mechanical rotational work.
- **Option D:** A DC generator produces unidirectional electrical current using a split-ring commutator.

Question #74 Key: (C)PHYSICS
11. Electromagnetic Induction

The induced current flows in such a direction as to oppose the cause that produces it. This sta...

CORE CONCEPT & DERIVATION

Lenz's Law states that the polarity of an induced electromotive force produces an induced current whose magnetic field directly opposes the initial change in magnetic flux that generated it.

Formula / Rule / Reaction:

$$\mathcal{E} = -N \frac{\Delta \Phi_B}{\Delta t}$$

Solution:

- Lenz's Law is a physical embodiment of the law of conservation of energy applied to electromagnetic induction.
- The minus sign in Faraday's mathematical equation represents Lenz's Law, ensuring that work must be done against the opposing induced magnetic field to generate electricity.

Why other options are incorrect:

- **Option A:** Ampere's Law relates magnetic field circulation along a closed path to the net enclosed electric current ($\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I_{\text{enc}}$).
- **Option B:** Faraday's Law quantifies the magnitude of induced emf as proportional to the time rate of change of magnetic flux.
- **Option D:** Joule's Law quantifies the rate of thermal energy dissipation by an electric current through a resistive conductor ($P = I^2 R$).

Question #75 Key: (C)PHYSICS
13. Electronics*The device used for conversion of AC into DC is a:***CORE CONCEPT & DERIVATION**

A rectifier is an electrical circuit or apparatus composed of semiconductor diodes designed specifically to convert bidirectional alternating current into unidirectional direct current.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- While individual p-n junction diodes provide the unidirectional conduction mechanism, the operational apparatus or complete circuit performing AC-to-DC conversion is designated as a rectifier.
- Rectifiers are categorized into half-wave configurations (using a single diode) and full-wave configurations (center-tapped or bridge rectifiers using multiple diodes).

Why other options are incorrect:

- **Option A:** A diode is the discrete two-terminal electronic component; the assembled functional circuit that converts AC to DC is called a rectifier.
- **Option B:** An amplifier increases the amplitude, voltage, or power of an incoming electrical signal without rectifying its waveform.
- **Option D:** A transistor is a three-terminal semiconductor device used for switching and signal amplification.

Question #76 Key: (A)PHYSICS
13. Electronics*The process of conversion of AC into DC is called:***CORE CONCEPT & DERIVATION**

Rectification is the physical electronic process of converting a periodically reversing alternating current (AC) waveform into a unidirectional direct current (DC) waveform.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- The process utilizing unidirectional conducting elements to suppress or invert alternate half-cycles of alternating voltage is termed rectification.
- The circuit or hardware unit performing this task is termed the rectifier, whereas the process itself is rectification.

Why other options are incorrect:

- **Option B:** Amplification is the process of magnifying signal power or amplitude.
- **Option C:** Rectifier is the noun designating the physical device, not the process.
- **Option D:** Conversion is a broad generic category that does not identify the specific electronic process.

Question #77 Key: (D)PHYSICS
16. Nuclear Physics

A [Formula] phosphorus sample decays and [Formula] remains undecayed after [Formula]. The half...

CORE CONCEPT & DERIVATION

Radioactive decay obeys first-order kinetics; the fraction of undecayed parent nuclei remaining after n half-lives is given by $(1/2)^n$.

Formula / Rule / Reaction:

$$N(t) = N_0 \left(\frac{1}{2}\right)^n \quad \text{and} \quad n = \frac{t}{T_{1/2}}$$

Solution:

- Calculate the ratio of surviving mass to initial mass:

$$\frac{N(t)}{N_0} = \frac{2 \text{ g}}{32 \text{ g}} = \frac{1}{16} = \left(\frac{1}{2}\right)^4$$

- This reveals that exactly $n = 4$ half-lives have elapsed across the 60-day period.

- Determine the half-life:

$$T_{1/2} = \frac{t}{n} = \frac{60 \text{ days}}{4} = 15 \text{ days}$$

Why other options are incorrect:

- Option A:** 5 days would mean 12 half-lives elapsed in 60 days, leaving only 32/4096 g.
- Option B:** 6 days corresponds to 10 elapsed half-lives, leaving 0.031 g.
- Option C:** 10 days corresponds to 6 elapsed half-lives, leaving 0.5 g.

Question #78 Key: (A)PHYSICS
03. Work & Energy

The SI unit of gravitational potential is:

CORE CONCEPT & DERIVATION

Gravitational potential at a point in space is defined as the work done per unit mass in bringing a test body from infinity to that point within the gravitational field.

Formula / Rule / Reaction:

$$V_g = \frac{W}{m} = -\frac{GM}{r} \implies [V_g] = \frac{\text{J}}{\text{kg}} = \text{m}^2 \cdot \text{s}^{-2}$$

Solution:

- Work (energy) has the SI derived unit of joules (J).
- Mass has the SI fundamental base unit of kilograms (kg).
- Dividing work by mass yields the SI unit of gravitational potential as joules per kilogram (J/kg).

Why other options are incorrect:

- Option B:** Dividing by meters introduces an extraneous length dimension, which represents gravitational field strength per unit mass rather than potential.
- Option C:** Incorporating seconds in the denominator is dimensionally invalid for potential.
- Option D:** Joules per second (J/s) defines the watt (W), the SI unit of power.

Question #79 Key: (C)PHYSICS
16. Nuclear Physics*In nuclear radiography for medical diagnosis, which rays are used?***CORE CONCEPT & DERIVATION**

Nuclear medicine diagnostic techniques (such as scintigraphy and SPECT) use internally administered radioisotopes that emit penetrating gamma rays detected externally by scintillation cameras.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- In nuclear radiography, radioactive tracers (such as Technetium-99m) are introduced into the physiological system.
- These tracers emit high-energy gamma photons that readily penetrate surrounding soft tissue and bone, allowing external gamma cameras to image organ function and pathology.

Why other options are incorrect:

- **Option A:** Alpha particles possess high ionizing power but minimal tissue penetration (stopped by a few micrometers of tissue), causing localized radiation necrosis without escaping the body for imaging.
- **Option B:** Ultraviolet radiation is non-ionizing optical radiation unable to penetrate beneath the stratum corneum of the epidermis.
- **Option D:** X-rays are generated by high-voltage vacuum tubes for external transmission radiography (CT and plain radiographs), whereas nuclear radiography relies on internally administered radionuclides emitting gamma rays.

Question #80 Key: (C)PHYSICS
03. Work & Energy*The SI unit of linear momentum is:***CORE CONCEPT & DERIVATION**

Linear momentum is defined as the product of mass and velocity; by Newton's second law, momentum change equals mechanical impulse, giving it units of newton-seconds.

Formula / Rule / Reaction:

$$\vec{p} = m\vec{v} \Rightarrow \vec{J} = \Delta\vec{p} = \vec{F}\Delta t \Rightarrow [p] = \text{kg} \cdot \text{m} \cdot \text{s}^{-1} = \text{N} \cdot \text{s}$$

Solution:

- In SI base units, momentum is expressed as kilogram meters per second ($\text{kg} \cdot \text{m} \cdot \text{s}^{-1}$).
- Recalling that one newton is $1 \text{ N} = 1 \text{ kg} \cdot \text{m} \cdot \text{s}^{-2}$, multiplying newtons by seconds yields:

$$\text{N} \cdot \text{s} = (\text{kg} \cdot \text{m} \cdot \text{s}^{-2}) \cdot \text{s} = \text{kg} \cdot \text{m} \cdot \text{s}^{-1}$$

Why other options are incorrect:

- **Option A:** Newton-meter ($\text{N} \cdot \text{m}$) is the unit of torque or energy (joule).
- **Option B:** Newton per second (N/s) represents the time rate of change of force (yank).
- **Option D:** Newton-second squared ($\text{N} \cdot \text{s}^2$) corresponds to mass times distance, which is dimensionally incorrect.

Question #81 **Key: (B)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Fill in the blanks with the most appropriate option: When we went to cinema, the film _____.

CORE CONCEPT & DERIVATION

When two past actions are related in time, the earlier completed action requires the past perfect tense (had + past participle), while the later action is stated in the simple past.

Formula / Rule / Reaction:

Action 1 (Earlier in past) : had + past participle vs. Action 2 (Later in past) : simple past (went)

Solution:

- The arrival at the cinema is a past event denoted by the simple past verb "went".
- Because the screening of the movie began prior to this arrival, the past perfect construction "had already started" is grammatically required.

Why other options are incorrect:

- **Option A:** "Already started" lacks the auxiliary "had", failing to signal the earlier completed past action.
- **Option C:** "Would already start" expresses a conditional or habitual aspect, which is incorrect in this temporal sequence.
- **Option D:** "Started already" uses simple past tense and misplaced adverbial positioning, failing to convey temporal precedence.

Question #82 **Key: (B)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

The soup _____ good.

CORE CONCEPT & DERIVATION

Verbs of sensory perception (taste, smell, sound, look) function as stative linking verbs taking simple present tense and an adjective complement when describing inherent qualities.

Formula / Rule / Reaction:

Singular Subject (3rd Person) + Stative Verb (-s/-es) + Predicate Adjective

Solution:

- The subject "The soup" is an uncountable singular noun requiring a third-person singular verb ending in "-s".
- Because "taste" denotes a static quality of the soup rather than a deliberate physical action, stative simple present "tastes" is grammatically required.

Why other options are incorrect:

- **Option A:** "Taste" is the plural or base form, violating subject-verb agreement with the singular noun "soup".
- **Option C:** "Is tasting" uses the continuous aspect, which is used when an active agent samples food, not for an intrinsic quality.
- **Option D:** "Will tasting" is an ungrammatical modal auxiliary construction.

Question #83 **Key: (C)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

She _____ unconscious since 4 o'clock.

CORE CONCEPT & DERIVATION

The present perfect tense is required to express a state that began at a specified point in the past and continues unbroken into the present, especially when governed by the preposition "since".

Formula / Rule / Reaction:

Subject + has/have been + Complement + since + Point in Time

Solution:

- The temporal marker "since 4 o'clock" establishes a starting point in the past that continues up to the present moment.
- The singular subject "She" requires the third-person singular present perfect form "has been".

Why other options are incorrect:

- **Option A:** "Is" is simple present tense and cannot be paired with a past temporal starting boundary marked by "since".
- **Option B:** "Was" is simple past tense, implying that the period of unconsciousness has ended and no longer connects to the present.
- **Option D:** "Would" is a modal auxiliary verb requiring a base verb complement, leaving the clause grammatically incomplete.

Question #84 **Key: (B)**ENGLISH
03. Parts of Speech, Prepositions & Modifiers*We will stay here _____ Monday.***CORE CONCEPT & DERIVATION**

Prepositions of time indicate terminal limits of an action; "till" and "until" denote continuity up to a specified end point.

Formula / Rule / Reaction:

Action + till / until + Terminal Boundary Time

Solution:

- The sentence denotes an action in the future ("will stay") lasting up to a terminal day ("Monday").
- While both "until" and "till" convey this meaning, "Till" represents the officially keyed choice in the provincial examination paper.

Why other options are incorrect:

- **Option A:** Although "until" is formal and grammatically synonymous, the examining board rubric keyed Option B.
- **Option C:** "Still" is an adverb expressing continuity or static condition, not a temporal preposition.
- **Option D:** "Since" marks the beginning of an event from a past reference point, not an endpoint in the future.

Question #85 **Key: (B)**ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling*The word curiosity means:***CORE CONCEPT & DERIVATION**

Curiosity denotes an eager desire to learn, investigate, or acquire knowledge, matching the semantic definition of keenness or inquisitiveness.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Curiosity stems from Latin *curiosus* (inquisitive, careful).
- Among the provided distractors, "keen" denotes an eager, intense interest or sharpness of attention, representing the closest semantic match.

Why other options are incorrect:

- **Option A:** "Cruel" means willfully causing pain or suffering to others.
- **Option C:** "Angry" describes feeling or showing strong resentment or wrath.
- **Option D:** "Killing" denotes the act of causing death.

Question #86 **Key: (D)**ENGLISH
03. Parts of Speech, Prepositions & Modifiers*DRAWBACK, this word is a combination of:***CORE CONCEPT & DERIVATION**

Compound nouns are frequently constructed by combining a base verb stem with a spatial or directional adverb particle.

Formula / Rule / Reaction:

Draw (Verb) + Back (Adverb Particle) → Drawback (Compound Noun)

Solution:

- The constituent morpheme "draw" functions as a verb meaning to pull or retract.
- The morpheme "back" functions as an adverb particle denoting reverse direction.
- Their combination produces the compound noun "drawback", denoting a disadvantage, defect, or hindrance.

Why other options are incorrect:

- **Option A:** "Back" does not function as an adjective in this verbal-particle compounding construction.
- **Option B:** "Draw" is an action verb root rather than an initial noun.
- **Option C:** "Back" operates as an adverbial particle rather than a noun in this compound.

Question #87 Key: (B)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

I wish I _____ the answer.

CORE CONCEPT & DERIVATION

Clauses following the verb "wish" expressing an unreal, counterfactual desire about a present state require the past subjunctive (simple past tense).

Formula / Rule / Reaction:

Subject + wish + (that) + Subject + Past Subjunctive (Simple Past)

Solution:

- The sentence expresses a counterfactual longing about the present (the speaker currently does not know the answer).
- Under English grammatical rules governing hypothetical wish clauses, the verb must shift back into the simple past tense ("knew").

Why other options are incorrect:

- **Option A:** "Will know" expresses simple future indicative certainty, which is incorrect in an unreal wish clause.
- **Option C:** "Have known" is present perfect indicative, which cannot represent an unreal present condition.
- **Option D:** "Know" is present indicative, failing to reflect the subjunctive mood.

Question #88 Key: (B)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

What does the word "Analogue" mean?

CORE CONCEPT & DERIVATION

An analogue is a person, structure, or thing that is analogous, parallel, or comparable to another in key functions or characteristics.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The term "analogue" derives from Greek *analogos* (proportionate, corresponding).
- When two entities share equivalent structural or functional attributes, they are considered comparable analogues.

Why other options are incorrect:

- **Option A:** "Opposite" denotes complete contradiction or inverse relation, the antonym of analogue.
- **Option C:** "Behind" indicates spatial or chronological lag.
- **Option D:** "Clock" is an instrument that may display time using an analog dial, but the word "analogue" itself means comparable.

Question #89 Key: (A)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

What does the word "Pulsating" mean?

CORE CONCEPT & DERIVATION

Pulsating is a participial adjective describing rhythmic expansion and contraction, vibration, or throbbing.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Pulsating originates from the Latin verb *pulsare*, meaning to beat or strike repeatedly.
- "Throbbing" describes the same repetitive, rhythmic pulsation, making it the accurate lexical synonym.

Why other options are incorrect:

- **Option B:** "Pressure" is a physical force per unit area, not an oscillatory rhythmic movement.
- **Option C:** "Fluid" denotes a state of matter (liquid or gas) that flows, not an oscillation.
- **Option D:** "Heart beat" is a compound noun naming the cardiac cycle rather than a participial adjective describing rhythmic movement.

Question #90 Key: (A)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

The person in charge of a school is called:

CORE CONCEPT & DERIVATION

Homophones share identical pronunciation but differ in spelling and definition; "principal" denotes a chief executive or school administrator, whereas "principle" refers to a rule or moral doctrine.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- "Principal" functions as a noun designating the chief administrative head of an educational institution.
- In contrast, "principle" is a noun signifying a fundamental truth, law, or guiding doctrine.

Why other options are incorrect:

- **Option B:** "Principle" is a fundamental law, belief, or ethical standard, never a person.
- **Option C:** "Head" is an informal descriptor, whereas "principal" is the formal institutional title tested.
- **Option D:** "Staff" refers collectively to the employees of an organization rather than the single administrative head.

Question #91 Key: (C)ENGLISH
02. Idioms, Phrasal Verbs & Literary Figures*Break a leg is commonly used to:***CORE CONCEPT & DERIVATION**

Idiomatic expressions carry non-literal figurative meanings; "break a leg" is a traditional theatrical idiom used to wish performers success and good fortune.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- Rooted in theatrical superstition that directly wishing someone good luck invites misfortune, performers say "break a leg" instead.
- In contemporary English, the phrase is widely used beyond the theater to wish someone good luck before a major endeavor or presentation.

Why other options are incorrect:

- **Option A:** Despite its literal wording, the idiom is never used as an offensive curse or malediction.
- **Option B:** The idiom does not denote actual physical bone injury or bodily assault.
- **Option D:** Teaching someone a lesson means punishing someone for an error, unrelated to this idiom.

Question #92 Key: (B)ENGLISH
02. Idioms, Phrasal Verbs & Literary Figures*Bite the bullet is commonly used to:***CORE CONCEPT & DERIVATION**

"Bite the bullet" is an idiom meaning to face a painful, grim, or unavoidable situation with courage, endurance, and stoic fortitude.

Formula / Rule / Reaction:*Factual recall / Qualitative concept.***Solution:**

- The expression originates from historical military surgery, where wounded soldiers bit on lead bullets to endure painful procedures before anesthesia was available.
- In modern figurative usage, it signifies accepting difficult circumstances or facing unavoidable consequences stoically.

Why other options are incorrect:

- **Option A:** "Accept defeat" corresponds to idioms like "throw in the towel" or "wave the white flag".
- **Option C:** "Accept death" signifies passive resignation to mortality, whereas biting the bullet denotes enduring hardship to move forward.
- **Option D:** "Bad faith" refers to intentional deception or duplicity, which has no connection to this idiom.